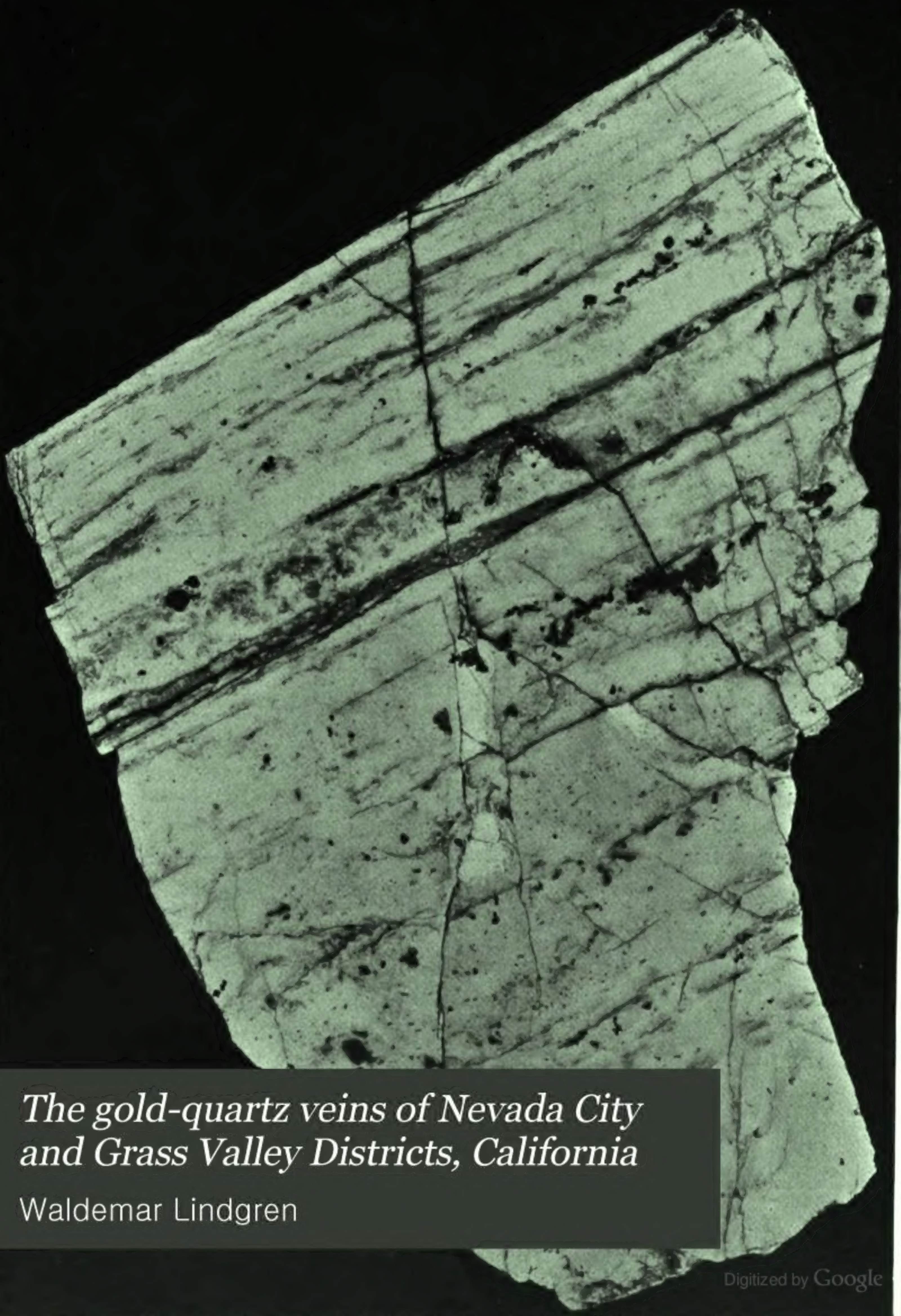


The gold-quartz veins of Nevada City and Grass Valley Districts, California

Waldemar Lindgren

Retain.
K. Cutler
6/3/76

Retain.
K. Cutler
6/3/76

Mr. H. W. Turner
with the kind regards of the author

DEPARTMENT OF THE INTERIOR—U. S. GEOLOGICAL SURVEY
CHARLES D. WALCOTT, DIRECTOR

THE GOLD-QUARTZ VEINS

OF

NEVADA CITY AND GRASS VALLEY DISTRICTS, CALIFORNIA

BY

WALDEMAR LINDGREN

EXTRACT FROM THE SEVENTEENTH ANNUAL REPORT OF THE SURVEY, 1895-96
PART II—ECONOMIC GEOLOGY AND HYDROGRAPHY

WASHINGTON
GOVERNMENT PRINTING OFFICE
1896

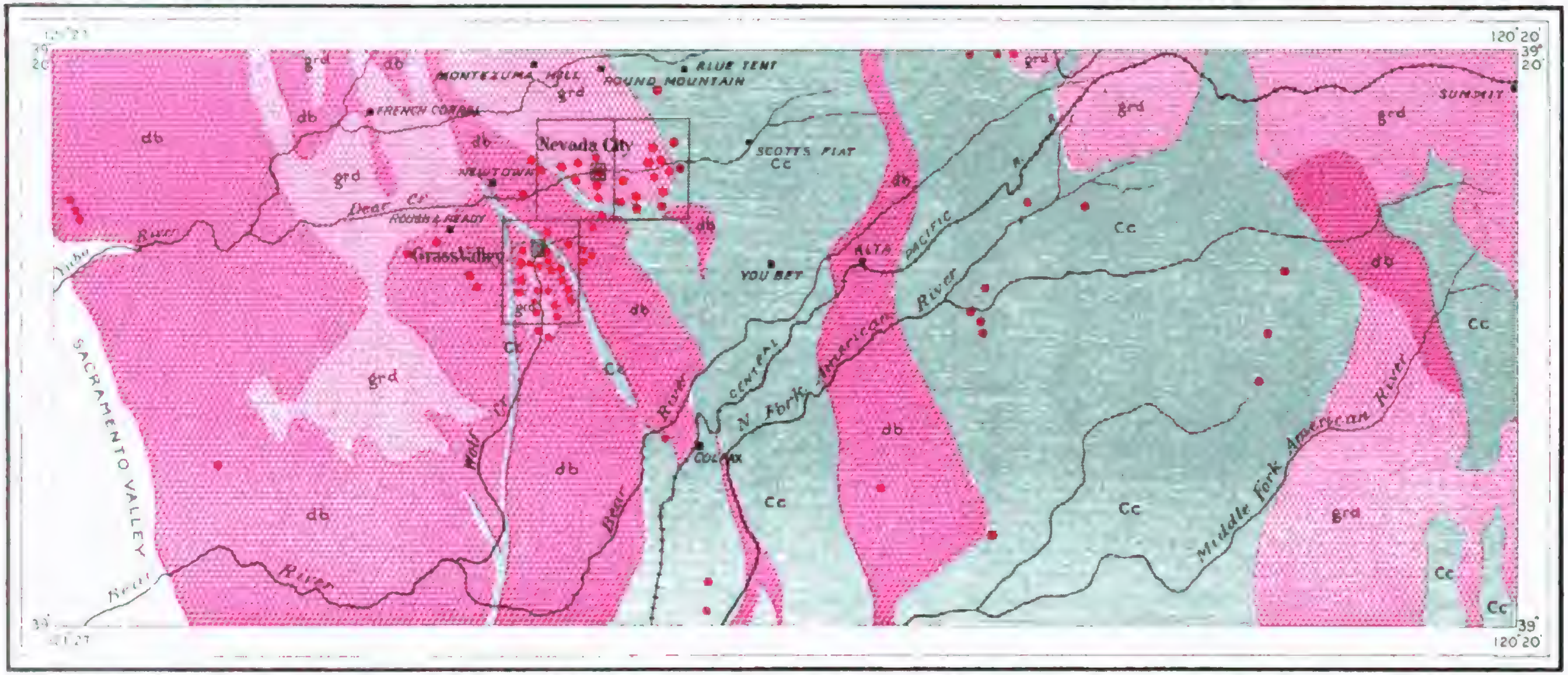
THE GOLD-QUARTZ VEINS OF NEVADA CITY AND GRASS VALLEY DISTRICTS, CALIFORNIA.

BY

WALDEMAR LINDGREN.

CONTENTS.

ILLUSTRATIONS.



MAP OF PART OF SIERRA NEVADA, SHOWING PRINCIPAL BEDROCK FORMATION AND LOCATION OF SPECIAL SHEETS

BY W. LINDGREN.

grd GRANODIORITE.

db DIABASE, PORPHYRITE, GABBRO, DIORITE, SERPENTINE AMPHIBOLITE.

Cc SEDIMENTARY ROCKS, CHIEFLY JURATRIAS, JURA AND CARBONIFEROUS.

GOLD-QUARTZ MINES.

Scale of miles.

5 0 5 10 15

THE GOLD-QUARTZ VEINS OF NEVADA CITY AND GRASS VALLEY DISTRICTS, CALIFORNIA.

By WALDEMAR LINDGREN.

CHAPTER I.

INTRODUCTION.

FIELD WORK AND ACKNOWLEDGMENTS.

The field work on which this report is based was begun September 20, 1893, and continued without interruption until June 28, 1894. The topographic maps used were prepared in 1891 by Messrs. A. F. Dunnington and R. B. Marshall, with triangulation by Mr. E. M. Douglas, on a scale of $\frac{1}{14400}$, or about 4 inches to the mile. They comprise three sheets, each embracing about 12 square miles, named respectively the Nevada City, Banner Hill, and Grass Valley sheet. The geological and topographic maps, the latter with the outline of mining claims indicated, have been published as a folio of the Geologic Atlas of the United States. For present purposes a map on the reduced scale of $\frac{1}{28800}$ has been prepared from the full-size sheets of the folio.

The chemical analyses have been made by Messrs. W. F. Hillebrand, H. N. Stokes, George Steiger, and Peter Fireman.

To the mine owners and superintendents of the districts many thanks are due for the courtesy and assistance extended by them in the work of examining the mines. I also take great pleasure in acknowledging my special obligation to Mr. E. C. Uren, of Grass Valley, and Messrs. W. F. Englebright and W. W. Waggoner, of Nevada City, for much valuable information and cooperation.

GEOGRAPHIC POSITION.

The important gold-mining districts here described are located in Nevada County, on the long western slope of the Sierra Nevada, at an average elevation of 2,500 feet and about 15 miles north-northwest of the town of Colfax, on the Central Pacific Railroad.

The map appended to this paper shows the topography and geology on a scale of about 2 inches to the mile. The northern part comprises the Nevada City sheet on the west and the Banner Hill sheet on the east. The southern and smaller part consists of the Grass Valley sheet; the small area mapped outside of the northeastern corner of this sheet is referred to as the Brunswick tract.

TOPOGRAPHY.

RELIEF.

The dominating features in the northern part of the tract are the two long ridges whose crests descend gently westward—the Harmony Ridge, near the northern boundary, and the Banner Hill-Towntalk Ridge, near the southern boundary. The northern ridge sinks with a gradual slope from an elevation of 3,660 feet to 2,840 feet at the western boundary line of the Nevada City map, and is cut in two by a gap north of Nevada City. A conspicuous pyramidal hill, the Sugarloaf, with an elevation of 3,075 feet, stands in the middle of the gap and reaches at its summit the gradient of the ridge line. The southern ridge, beginning at an elevation of 3,600 feet, is somewhat wider than the northern, and has at the western boundary line of the map an elevation of 2,700 feet. Near Banner Hill this ridge is cut in two by the narrow canyon of Little Deer Creek; farther west several gaps are cut across it, the most prominent one being that at Towntalk. The average slope of the ridge line is 1½°. At the eastern boundary of the Banner Hill district the ridges approach each other, and are in fact separated only by the deep canyon of Deer Creek. In the southeast corner of the Banner Hill tract, towering 500 feet above the ridges, stands the isolated and conspicuous Banner Hill (elevation 3,904 feet). From the edges of the ridge tables steep slopes lead down to the watercourses, steepest as a rule near the summit, then flattening out somewhat, then again becoming steeper toward the stream bed. The distance between the ridges is greatest at the western edge of the Nevada City tract, and here, as well as south of Nevada City, the relief is less accentuated.

The general relief of the Grass Valley tract is gentler and the outlines are more undulating than those of the region described above. The elevations range from 3,080 feet on the summit of Osborne Hill to 2,080 in the bed of Wolf Creek, at the southern boundary. The northeastern part consists of a series of rather flat-topped ridges, 200 to 300 feet high, with comparatively steep slopes toward the watercourses. The larger, southwestern part may be considered as an undulating plateau, with somewhat irregular hills and ridges rising to a height of 100 or 200 feet above the general level. In this plateau the principal drainage line has cut a canyon, which in some places is narrow and steep, and the depth of which does not exceed 300 feet. Rising high above the other relief and occupying a position similar to that of Banner Hill, stands the high ridge of Osborne Hill.

DRAINAGE.

The principal stream is Deer Creek, which traverses the middle of the region from east to west, and which, 12 miles farther west, empties into the Yuba River. The total fall of the stream from the eastern side of the Banner Hill tract (elevation, 2,840 feet) to the western side

of the Nevada City tract (elevation, 2,160 feet) is 680 feet, or about 100 feet to the mile. The fall is by no means uniform, however. In the steep canyon in the eastern part of the Banner Hill tract it is 150 feet to the mile; thence down to Nevada City about 100 feet to the mile; from Nevada City to the Providence mine, through another narrow canyon, the fall is 150 feet to the mile; and from the Providence down to the edge of the tract it is but 53 feet to the mile, the creek meandering over gravelly flats. Lateral ravines, usually steep and narrow, lead to the creek from north and south. A somewhat larger tributary is Little Deer Creek, which heads in the vicinity of Banner Hill. South of Towntalk the drainage is toward Bear River, the ravines forming the northern headwaters of Wolf Creek, a tributary of that river. Southeast of Banner Hill the steep ravines lead down toward Greenhorn Creek, also a tributary of Bear River. The larger part of the area in the southern part of the tract is drained by Wolf Creek, a tributary of Bear River. From the city of Grass Valley it runs south to the limit of the tract without larger tributaries. At Grass Valley it forks into two creeks, which have a general east-west direction. The fall varies from 50 feet to the mile in the Grass Valley basin to 130 in the vicinity of the Omaha mine. The smaller tributaries to the creek show a feature which is also marked in the other two tracts, though to a less extent; they flow with gentle grade over the undulating, plateau-like country, even forming marshes at their sources, but on approaching the main stream they descend to it with a steep, torrential grade. East of Osborne Hill the drainage is toward Rattlesnake Creek, a tributary of Wolf Creek. The extreme northwestern corner drains to Deer Creek.

VEGETATION.

The vegetation is of generally uniform character throughout the district, and consists predominantly of a second growth of yellow pine (*Pinus ponderosa*), the much more luxuriant growth once covering a large part of the ground having been cut for mining purposes since 1849. A few large white-oaks are found on the more open flats, and a strong bushy growth of chaparral (Manzanita and Ceanothus) covers some of the hills. The serpentine ridges have a separate and peculiar vegetation of digger-pine (*Pinus sabiniana*)—elsewhere rarely growing above 2,000 feet—yew, stunted oak, and thorny bushes.

LITERATURE.

The references to the mining industries of the districts are very scattered and consist chiefly in descriptions of individual mines. The more important of them are contained in the following list. In the preparation of this report the statements in Bean's Directory, Raymond's and J. Ross Browne's reports, Burchard's mint reports, and the reports of the State mineralogist have been frequently consulted and used. Bean's

Directory is unquestionably the best and most extensive as well as the most reliable report extant of the districts up to the year 1866. In these publications the geological features generally occupy a very subordinate space, most observations being confined to character of veins and ore shoots, production, and technical data.

W. P. BLAKE. Explorations and surveys for a railroad route from the Mississippi River to the Pacific Ocean, Vol. V, p. 268.

Notes made in 1853. Contains statements in regard to the Empire and Gold Hill veins, etc.

JOHN S. HITTELL. Mining in the Pacific States of North America. San Francisco, 1861. 224 pages.

P. LAUR. Du gisement et de l'exploration de l'or en Californie. Ann. des mines, Vol. III, 1863, p. 412.

Notes from many mines in the vicinity. Advocates Tertiary age of quartz veins and gradual decrease of tenor in depth.

J. ROSS BROWNE. Report upon the mineral resources of the States and Territories west of the Rocky Mountains. Washington, 1867.

Contains notes on many mines of the district, tables of production and stamps, statements on early mining laws, etc., also a résumé by William Ashburner on the Grass Valley mines.

J. ROSS BROWNE. Report upon the mineral resources of the States and Territories west of the Rocky Mountains. Washington, 1868.

Contains notes of many mines in the district, chiefly from Bean's Directory.

BEN SILLIMAN, Jr. Notes on the Grass Valley mining district. Am. Jour. Sci., 2d series, Vol. XLIV, pp 236–244. 1867.

Contains description and notes of several Grass Valley mines, notably of the Eureka, notes in regard to the geology of Grass Valley, etc. Professor Silliman speaks of the greenstones as probably altered sediments, refers to the presence of syncline and anticline, and considers the quartz veins as conforming to the stratification. The jointing or sheeting has evidently been mistaken for stratification. Occurrence of ore shoots is excellently explained, and the view of impoverishment in depth is combated.

BEAN'S HISTORY AND DIRECTORY OF NEVADA COUNTY. Compiled by Edwin F. Bean. Nevada, 1867.

An excellent book, giving historical data of the development of the district, as well as detailed notes in regard to nearly every vein and placer then worked, chiefly in regard to yield and ownership. Out of print and very rare.

R. W. RAYMOND. Report on the mineral resources of the States and Territories west of the Rocky Mountains, Vols. I to VIII, comprising 1869–1877.

Contains numerous notes in regard to mines of the district.

AMOS BOWMAN. Report on the properties and domain of the California Water Company, situated on the Georgetown divide. San Francisco, A. L. Bancroft & Co., 1874. Also in Raymond reports, Vol. VII, 1879, pp. 441–470.

Contains a few notes on Grass Valley mines and many references to other localities in the Gold Belt. Also contains a map showing strike of the most important veins of the Gold Belt. Book very rare and out of print.

H. C. BURCHARD. Report of the Director of the Mint upon the statistics of the production of the precious metals in the United States. 1881, 1882, 1883, 1884.

Contains numerous notes, chiefly on the production of Nevada City and Grass Valley mines.

J. D. WHITNEY. The auriferous gravels of the Sierra Nevada of California. Memoirs. Mus. Comp. Zool. Harvard Coll., Vol. VI, No. 1. Cambridge, 1880.

Notes and description of gravel mines in the districts, by J. D. Whitney and W. H. Pettee.

REPORTS OF THE STATE MINERALOGIST OF CALIFORNIA. Sacramento, Cal. Vols. I to XII, 1880 to 1895.

Numerous notes and descriptions of quartz and placer mines in the district, by Melville Attwood, J. B. Hobson, and E. A. Wiltsee. Also a paper on the "Lithology of Wall-rocks," by Melville Attwood, describing the Eureka and Idaho mines (8th Ann. Rept., pp. 771-784.) Also a map by Ross E. Browne, of the Harmony gravel mines (12th Ann. Rept.).

J. ARTHUR PHILLIPS. The mining and metallurgy of gold and silver. London, 1868.

Contains notes from personal observation on some Grass Valley mines, and also excellent observations on ore shoots, etc. Shows that the gold ores do not decrease in tenor with depth.

F. G. CORNING. The gold quartz mines of Grass Valley, Cal. Eng. and Min. Jour., Dec. 11, 1886, p. 418.

E. REYER. Ueber die Goldgewinnung in Californien. Zeitsch. für Berg-, Hütten- und Salinenwesen im preuss. Staate, Vol. XXXIV, pp. 1-28, 1886.

Geological sketch of Grass Valley and Nevada City; notes on Eureka and Idaho mines. The determination of rocks is not altogether satisfactory; data presented apparently showing gradual decrease in value of ores in depth.

W. M. COURTIS. Gold quartz. Trans. Am. Inst. Min. Eng., Vol. XVIII, pp. 639-644, Oct., 1889.

Describes microscopic sections of gold-bearing quartz from Grass Valley and other places.

NEVADA COUNTY MINING REVIEW. Published by the Daily Morning Union. Grass Valley, 1895.

Contains short descriptions of the various mines in operation at the present time.

HISTORY.[1]

Previous to the middle of the present century this region, as well as the whole Sierra Nevada, was an unbroken wilderness; the region above an elevation of 2,000 feet was covered with magnificent forests of sugar pine, yellow pine, and fir. Nevada City and Grass Valley were located at the lower limit of this luxuriant and virgin forest.

Once opened up by the army of gold seekers, the progress of the country was rapid; marvelous indeed are the changes wrought in the short forty-eight years elapsed since the discovery of the gold in 1848.

The first discovery of gold in the Sierra Nevada is, as is well known, credited to J. W. Marshall, who on January 19, 1848, found some nuggets in the mill-race while constructing a sawmill at Coloma, Eldorado County, for General Sutter, of Sutter's Fort, now Sacramento.

The first gold found within the boundaries of Nevada County is said to have been panned out by Jonas Spect on Rose Bar, on the Yuba River, north of Smartsville, June 2, 1848. Marshall himself is stated to have visited Nevada County in the summer of 1848, while escorting a party of immigrants across the mountains. He camped on Deer Creek, near where Nevada City now stands, and tried a few pans of dirt, finding gold each time. In October, 1848, two prospectors came up Wolf Creek and camped a short time near where the Eureka and Idaho mines are now located.

During the summer and fall of 1849 the miners gradually worked up along the Middle and South Yuba, Bear River, Deer Creek, and their

[1] In the compilation of this brief historical review the sources mentioned above have been freely drawn upon.

principal tributaries. Several men were camping at Boston Ravine and Badger Hill, Grass Valley. Dr. Caldwell built the first store where Nevada City now stands, and sawmills were erected 4 miles south of Grass Valley. From that time the development of the districts, at first based principally upon the alluvial placer mines, went rapidly forward. In March, 1850, an alcalde was elected under the Mexican law at Caldwell's store, and the camp received its name of Nevada. In April of the same year the first hotel in Nevada City was erected. It was built of rifted pine boards, the whole house, 8 feet front and 48 in depth, being taken from one tree. The house opened on May 1 with 40 guests, the moderate price of board and lodging being $25 per week.

A town, called Coyoteville, grew up on the gravel hills in the northwestern part of the present Nevada City as soon as it was found that the hill gravels were rich. Several thousand men rushed in during 1850. Sawmills were erected, and the lumber sold at $200 per 1,000 feet. In the summer of 1850 a church was organized, and a paper appeared in 1851. In 1853 the first brick building was erected, and telegraphic communication with Sacramento and Marysville was established. In 1856 there were 907 occupied houses in Nevada City.

In Grass Valley several stores were opened in 1849 and 1850. The first town election was held in November, 1850. The first church was organized in 1851, and a school with 12 pupils opened in a log cabin the same year. After 1851 the growth of the town was very rapid. Like Nevada City, it was, however, subject to many fluctuations, caused by several rushes of the miners to newly reported gold regions, and by periods of depression and activity in the quartz-mining business.

In 1880 there were 20,833 inhabitants in Nevada County; in 1890, according to the last census, 17,369. This decrease is directly due to the cessation of hydraulic mining, prohibited shortly after the census of 1880 by the Federal courts, on account of damage wrought to the lowlands of Sacramento Valley.

Grass Valley township had in 1880 a population of 6,688; in 1890, 6,798. The population of the city is not given separately. Nevada City township had in 1880 a population of 5,506; in 1890, 4,013. The population of Nevada City is given as 4,022 in 1880, and 2,524 in 1890. Since 1890 both cities have increased not inconsiderably in population, due to the renewed interest in quartz mining.

DEVELOPMENT OF MINING INTERESTS.

PLACER MINING.

During the first years the alluvial placer mines furnished the largest amount of gold; in both districts such mines were actively worked during the first and even the second decade after the discovery. Very soon, however, the older, Tertiary hill gravels were discovered; the deposits of these were far richer and more abundant at Nevada City than in Grass Valley. Between 1856 and 1860, and between 1865 and

1870, the old channels on the Alta, Towntalk, and Independent hills, near Grass Valley, were worked by the drifting process. Very little hydraulic work was done about Grass Valley. At the present time there are practically no placer mines working in that vicinity.

As early as 1851 the hill gravels above Nevada City, both on the south and on the north side of the Sugarloaf, were discovered, and the town of Coyoteville, already alluded to, was established on the eastern end of Lost Hill. The methods of mining were at first primitive, small shafts being sunk and low drifts run in different directions. Sluices, the first improvement on the pan, rocker, and long-tom, were first used, it is said, in the Coyoteville diggings. In 1853 the first experiments in hydraulic mining, or sluicing with water under high pressure, were made in Nevada City, on American Hill, by E. G. Matteson. During the sixth and seventh decade hydraulic mining was carried on extensively about Nevada City. Writing in 1866, Bean remarks in his directory: "The placer mines are still worked quite extensively and are the main reliance of a large proportion of the population. There are a few companies conducting operations on a large scale, and generally with success, besides numerous independent miners working the gulches and ravines." At this time hydraulic plants were in operation on American Hill, Wet Hill, and Lost Hill; extensive ground sluicing was carried on on the head waters of Brush Creek, about Selby Flat, where the shallow gravels were extraordinarily rich. In 1858 to 1860 the rich Nebraska ground of the Manzanita channel was drifted. In 1870 the hydraulic mine on the Manzanita channel was being worked. The last hydraulic work about Nevada City at the time of the suppression of hydraulic mining was in the extreme northwest corner of the large hydraulic area on American Hill, and is referred to as Hirshmann's Cut. Since 1890 several drift mines have been in operation on the Harmony Ridge, notably the East and the West Harmony mines.

QUARTZ MINING.

The first find of gold-bearing quartz was made on Gold Hill by a German in September, 1850. The piece was sold for $5, and proved to be worth $100.[1] These and other finds were at first not thought much of. But in November, 1850, a rich ore shoot was struck on Gold Hill by miners digging a hole for their cabin chimney; pieces of this vein proved to contain $500 per ton. A great excitement followed, and in this and the two following years most of the quartz veins in the vicinity were located. At first the quartz was crushed in mortars with spring pole, and the Huff company took out $20,000 in this way in the winter and spring of 1851.

The first mill was put up in January, 1851. It was a rude affair and

[1] Letter by Senator A. A. Sargent, written January 1, 1856, and published in the Nevada Transcript, October 30, 1893.

proved practically useless. A second, 8-stamp mill was erected soon after, which was a little more useful. Rock from Gold Hill was crushed in it for $50 per ton. The miners were paid $12 per day. In the following years a number of mills were built, one of the best being erected by Melville Attwood in 1853. In 1853 W. P. Blake writes that several quartz mills were located along Boston Ravine, and describes the process in use at the mill of the Empire mine, which began to work in 1851, and with brief intermissions has continued until to-day. Whitney[1] writes at the same time that with the beginning of 1853 there were at least 20 Anglo-Californian companies in the London market, representing a capital of $10,000,000.

During 1851 there was a great excitement about quartz claims in Nevada City, rich gold quartz having been discovered. The Merrifield, Providence, and Gold Tunnel veins were located, and during the next year expensive reduction works were erected, all of which except the Gold Tunnel mill were conspicuous failures. Over $80,000 were expended by the "Bunker Hill" company on a smelting process, works for which were erected on the present Nevada City claim.

On account of the many failures, quartz mining at Grass Valley and Nevada City received a serious setback. At Grass Valley, where several mills were kept running, the industry slowly revived, but at Nevada City the miners turned their attention to the gravels, and quartz mining was almost neglected. In 1857 Grass Valley was flourishing and Nevada City mines were improving. From 1859 to 1862 the business was depressed and values in both districts depreciated greatly, owing partly to the great Washoe excitement, partly to the flooding of many mines during the winter of 1861–62. Again matters improved, and in 1867 Grass Valley was the most prominent camp in the State. In 1866, according to J. Ross Browne, there were 248 stamps, crushing 71,420 tons of ore, with an average yield of $30 to $35, in Grass Valley, and 142 stamps, crushing 14,200 tons, averaging $25, in Nevada City.

In 1873 (Raymond's report) the Grass Valley district produced about $2,000,000 (estimate of large mines only), raising 60,000 tons of ore, averaging $33, with 1 or 2 per cent sulphurets, while in Nevada City only $67,000 was produced from 9,000 tons of ore, averaging $7.50 per ton.

In 1880, according to the Tenth Census, 28,989 tons of ore were raised in the Grass Valley district, averaging $20.26; in the Nevada City district, 27,814 tons, averaging $22.52; and in the Willow Valley district, 1,630 tons, averaging $40. Neither the Tenth nor the Eleventh Census gives the number of stamps running. From the latter there are no definite data to be obtained, the production of the county only being given.

According to the table by Mr. J. B. Hobson, in the Tenth Annual Report of the State Mineralogist for 1889, there were, during that year,

[1] Metallic Wealth of the United States, Philadelphia, 1854, p. 142.

211 stamps in Grass Valley, crushing 69,054 tons of ore containing 1,721 tons sulphurets, or 2 per cent, with a total estimated value of free gold and sulphurets of about $1,285,000, or about $18 per ton; in Nevada City, 172 stamps, crushing 33,000 tons of ore containing 1,269 tons of sulphurets, or nearly 4 per cent, with a total value of free gold and sulphurets of about $402,500, or about $12 per ton.

A very decided improvement in the quartz-mining business was noticed in the beginning of the present decade. While in 1885 there were but few mines running and but little prospecting in progress, a great and increased activity was noted at the time this investigation was begun. Two hundred and fifteen stamps were dropping in Grass Valley and 170 in Nevada City during 1893, and several new mills have been erected since then.

Gold Hill and Massachusetts Hill were the principal producers during the first two decades. The Empire has worked almost continuously since 1851. The North Star was in operation until 1872, then again from 1884 to the present time. The Eureka pay shoot began to be exploited in 1864, and has been continuously worked since then in the Eureka, Idaho, and Maryland mines. At Nevada City the Gold Tunnel and California mines were among the earliest worked. The Providence and Nevada City mines have been exploited almost continuously, with short interruptions. The Sneath and Clay and the Pittsburg were large producers during the sixth and seventh decades. The Willow Valley veins have been worked intermittently.

In 1894 the following mines were producing:

NEVADA CITY.

Drift mines.—East Harmony and West Harmony.

Quartz mines.—Champion, Providence, Nevada City, Spanish, Mayflower, Federal Loan, and Pittsburg.

GRASS VALLEY.

Quartz mines.—Maryland, Empire, North Star, W. Y. O. D., Pennsylvania, Electric, Omaha, Slate Ledge, Osborne Hill, and Orleans.

MINING CLAIMS.

The first meeting of miners was held in Grass Valley January 13, 1851, on Massachusetts Hill, when a size of 30 by 40 feet was allowed for all claims, the boundaries in all cases being perpendicular. Later on, claims 100 feet square were allowed. The form of the quartz claims on Massachusetts Hill still shows the outlines of the earliest locations. Still later, in 1852, a uniform rule was adopted by the quartz miners of Nevada County by which "each prospector shall hereafter be entitled to 100 feet on a quartz ledge or vein and the discoverer shall be allowed 100 feet additional. Each claim shall include all the dips, angles, and variations of the vein." (Ross Browne's Report, Washington, 1867, p. 235.) This was still in force in 1866, and in fact until the Federal

mining laws were passed in 1872, allowing quartz claims to be 1,500 feet along the vein, with all the dips, spurs, and angles, and 600 feet wide.

PROCESSES OF MINING AND MILLING.

The scope of this paper does not permit a detailed explanation of the processes used in obtaining the gold from the gravel and the quartz. A few notes on the subject may, however, not be amiss for those not familiar with the methods employed.

HYDRAULIC MINING.

This method consists in directing a stream of water under pressure, ranging up to 400 feet, against high gravel banks. The quantity of water in one jet ranges up to 1,000 or even 1,500 miner's inches (10,000 to 15,000 gallons per minute, approximately). The disintegrating power of the jet is often aided by bank blasting, consisting in running small drifts in the bank and exploding heavy charges—up to 25,000 pounds—of black powder. The gravel is then led through a number of sluice boxes, aggregating at least 1,000 feet in length, in which the gold is caught in riffles of cobblestones or wooden blocks by the aid of added quicksilver. There are no data of the yield or cost of the hydraulic mining in Nevada City. Presumably, it was not much different from that of the other large hydraulic mines in the county. The top gravel is usually poor, containing from 2 to 10 cents per cubic yard, while the lowest part on the bed rock may be very rich. The minimum cost is probably about 3 cents per cubic yard.

DRIFT MINING.

This method consists in extracting the richest gravel on the bed rock of the old channels, opened up by means of tunnels, inclines, or vertical shafts. The gravel is rarely worked to a height of over 8 feet, the gold being mostly concentrated near the bed rock. The deposit is blocked out and exploited in a manner similar to the working of horizontal coal seams. The pay gravel is washed in sluices, rarely aggregating more than a few hundred feet in length, or when hard and cemented is crushed in stamp mills.

The cost varies greatly, according to conditions. Under the most favorable circumstances the expenses may be reduced to 90 cents per cubic yard; in mines worked by shafts or inclines, having to hoist the gravel and pump the water, the expense is increased to $2 or $3. The milling of the gravel, when necessary, is usually considered to cost 33 cents per ton.

QUARTZ MINING.

The method almost universally adopted of exploiting the quartz veins is by incline shafts, following the dip of the deposits. Levels

are turned usually every 100 feet, and the pay rock is extracted by overhand stoping. Perpendicular shafts are sometimes used to open veins with flatter dip.

The cost of mining varies considerably with the thickness of the vein, the hardness of the country rock, and the depth and amount of water in the mine. The generally narrow veins of Grass Valley necessitate so much dead work that the expenses are rather high. In the large veins of Nevada City the cost is stated in the mineralogist's reports to be $2.50 to $3 per ton, while in the North Star, a representative deep mine with narrow vein, it is $5. In certain mines of Grass Valley, working under disadvantages, it is even more—up to $6 and $7. The cost of mining has decreased considerably in the last twenty years. J. Ross Browne gives the cost at the Empire mine as $8.60 per ton in 1867, while at present it does not exceed $5. The power used is steam, water, or electricity.

MILLING.

The ores from both mining districts are called "free milling"—that is, they contain native gold easily amalgamating with quicksilver. They contain, also, however, a certain percentage of gold chemically combined or very intimately mixed with the metallic sulphurets which make up a small fraction of the ore. However fine the ore is crushed, there is always a certain, sometimes considerable, amount of gold going off with the sulphurets if these are allowed to escape. This was recognized early, and the saving of the gold in the sulphurets has been found the most difficult problem in the milling process.

W. P. Blake described the process in use at the Empire mill in 1853 as follows: The ore, after being roasted in heaps, is crushed in a 16-stamp mill; the pulp passes over blankets, where much gold and pyrites is caught; these blankets are wrung out in water at intervals, and the mixture of gold and pyrites is subjected to amalgamation in pans. From the blankets the pulp passes through a revolving cylinder holding mercury, where a part of the fine gold is amalgamated; finally the pulp is subjected to an amalgamation in a Blaisdell pan holding mercury and iron balls; three-fourths of the gold is caught on the blankets. The gradually elaborated process was in use for many years and is known as the Grass Valley process. W. A. Skidmore describes it as used in the Idaho mill in Raymond's reports for 1869 and 1870: The quartz is crushed very fine; there is no amalgamation in the battery. From the battery the pulp is passed over blankets which are washed out every fifteen minutes. The results from the blanket washings are passed through two Attwood amalgamators, where a revolving cylinder with rakes stirs the mass in a bed of quicksilver. The skimmings of the amalgamators are treated in two Knox pans with chemicals, and here 33 per cent of the gross yield is obtained. The pulp from blankets and amalgamators is passed in contact with revolving cylinders of

amalgamated copper plates, and the sulphurets are concentrated on improved Cornish buddles. The sulphurets are finally passed to the chlorination process. The average cost of milling in 1868 was generally over $2.

The chlorination process, obviating the shipping of the sulphurets to smelting works or the wasteful grinding in amalgamating pans, was successfully introduced in this region in 1860 by G. F. Deetken and O. Maltman, and has been in use continually since that time. The sulphurets are subjected to an oxidizing roasting, usually with addition of some chloride of sodium; the roasted ore is exposed to the action of chlorine gas in large vats, and the chloride of gold formed is extracted with water. From this solution the gold is precipitated in a metallic state by means of ferrous sulphate. The silver is leached by calcium hyposulphite and precipitated as sulphide of silver by calcium polysulphide. The charge of treating 1 ton of sulphurets is from $16 to $20. There are several chlorination works to which the miners usually sell their concentrates. Mines with their own chlorination works report the cost to be $8 or $9 per ton.

The process of the modern stamp mill differs considerably from the old Grass Valley process. The ore is crushed by rock-breakers and fed automatically to 900-pound stamps dropping 6 to 7 inches from 80 to 90 times a minute. Amalgamation in battery is commonly used. Thirty to 40 mesh screens are used for the discharge, which is only on one side. From the battery the pulp passes over broad 4 by 6 foot silvered amalgamating plates. From the plates the pulp goes to the vanners, self-discharging concentrators of the endless-belt type, with lateral or longitudinal oscillation. In a few mines, notably the Idaho-Maryland, the tailings from the concentrates are worked over again with different contrivances, but ordinarily they escape directly. The cost of milling has been greatly reduced in the last twenty years. In the North Star 30-stamp mill, under E. A. Abadie, superintendent, the cost during 1887 to 1893 averaged 82 cents per ton. The cost of milling in general may be said to vary between $1 and 50 cents per ton, exclusive of the treatment of the sulphurets.

LOSS OF GOLD.

While the stamp mill has been very much improved and the loss of gold very much lessened, still there is in many cases unquestionably room for improvement. Some mills may work the ore up to 90 per cent of the assay value,[1] but in the majority probably an average of 75 per cent only is recovered, and in individual cases the loss may be much greater. The mines whose ore contains tellurium or much sulphurets are particularly liable to lose much of the finely divided particles; galena is especially liable to escape in the sluices. A strict control

[1] According to J. H. Hammond, 82 to 95 per cent of the assay value of the ore was saved in the Empire and North Star mills.

over the process by continued assays of ore and tailings is too often lacking. The concentrators are made to work a pulp consisting of grains of all sizes; in larger mills this could be obviated by proper separation of the pulp by streams of ascending water; canvas plants for the saving of the frequently rich, finest slimes are at present rather the exception than the rule. Rich sulphuretted ore, worth $75 and above, should never be milled, but shipped to smelting works; the losses in the mill are in this case always heavy, and may be enormous if tellurium is also present.

THE CYANIDE PROCESS.

Attempts to introduce the cyanide process in this vicinity have thus far not succeeded. For the concentrates the process can hardly compete with the chlorination. The large amounts of tailings to which it could have been applied have been swept down Deer Creek and Wolf Creek instead of being stored up. It is not improbable, though, that it could be used for many of the finest slimes, at present not utilized, as has been done at the Utica mine in Calaveras County.

LITERATURE.

A. J. BOWIE, Jr. Hydraulic mining, New York, 1885,

J. H. HAMMOND. The auriferous gravels of California. Ninth Rept. State Mineralogist, 1889, pp. 105-138.

R. L. DUNN. Drift mining in California. Eighth Rept. State Mineralogist, 1888, pp. 736-770. River mining. Ninth Rept. State Mineralogist, 1889, pp. 262-281.

J. H. HAMMOND. Milling of gold ores in California. Eighth Rept. State Mineralogist, 1888, pp. 696-735.

E. B. PRESTON. California gold mill practice. State Min. Bureau, Bull. 6, 1895.

E. A. ABADIE. Gold milling at the North Star mine. Trans. Am. Inst. Min. Eng., Vol. XXIV, 1894.

PRODUCTION.

To determine correctly the production of any mining district in California since 1849 is a well-nigh hopeless undertaking, so deficient are the statistics. The best that can be done is to present an estimate based upon the known yield of later years and the estimated yield in the earlier times. As the product of these districts form an important part of the total gold production of California, that may first be stated in round figures. The figures for the years 1848 to 1865, inclusive, are taken from the estimate of Dr. H. Degroot;[1] for 1866 to 1878 from the estimates of the Director of the Mint;[2] and from 1879 to the present time the amounts have been determined by the Director of the Mint on the basis of more accurate information. The production is given in millions of dollars.

---

[1] Fourth Ann. Rept. State Mineralogist, p. 217.
[2] Eleventh Census, Mineral Industries, p. 40.

Estimated production of gold in California.

Year.	Millions of dollars.	Year.	Millions of dollars.	Year.	Millions of dollars.
1848	5	1865	28	1882	16.8
1849	23	1866	25	1883	14.1
1850	50	1867	25	1884	13.6
1851	55	1868	22	1885	12.7
1852	60	1869	22.5	1886	14.7
1853	65	1870	25	1887	13.4
1854	60	1871	20	1888	12.8
1855	56	1872	19	1889	13
1856	55	1873	18	1890	12.5
1857	54	1874	20.3	1891	12.6
1858	50	1875	17.6	1892	12
1859	48	1876	17	1893	12
1860	45	1877	15	1894	13.6
1861	40	1878	15.3	1895	15.3
1862	38	1879	17.6	Total	1,301.1
1863	35	1880	17.5		
1864	30	1881	18.2		

The production of Nevada County previous to 1881, when the estimates by counties was undertaken by the Mint, can be given only as a rough estimate. A. Delano, a banker and mine owner of Grass Valley, probably better conversant with the facts in question than anyone else, gave in 1873 an estimate of $105,000,000 as the output of Nevada County from 1849 to 1872, which, from its relation to the total gold product, seems very reasonable. From 1873 to 1880 there was an average total gold production of 17 millions in the State, and we may estimate the production of Nevada County during the whole of that period to have been 28.8 millions.

Estimated gold production of Nevada County, 1849 to 1895, inclusive.

Year.	Millions of dollars.	Year.	Millions of dollars.	Year.	Millions of dollars.
1849–1872	105	1886	3.2	1893	2.1
1873–1880	28.8	1887	1.6	1894	1.8
1881	3.7	1888	2.6	1895	1.8
1882	3.6	1889	2.1	Total	171.1
1883	3	1890	2		
1884	3	1891	2.2		
1885	2.6	1892	2		

Still less accurate information is there available for the production of the Nevada City and Grass Valley districts, which always, however,

forms the largest part of the sums contributing to the total of Nevada County. A very great amount was taken from the placers in the first decade. It was estimated[1] that up to January, 1855, $3,585,000 had been produced from the placer diggings in the immediate vicinity of Grass Valley, and many millions were also taken from the surface placer mines of the Nevada City district. The Shelby Flat and Brush Creek diggings have yielded several millions; the high gravels of Lost Hill, Wet Hill, and American Hill several more; the Manzanita Channel about 3 millions. Mr. Delano estimates (loc. cit.) the total product of the Grass Valley district from 1849 to 1872 at 40 millions, and that of the Nevada City district to be the same amount, which seems somewhat high when compared with the total estimated output of the county. Mr. William Ashburner estimates[2] the product of the quartz mines of Grass Valley to be not less than 23 millions for the period 1852 to 1866, to which amount Massachusetts Hill alone contributed 7 millions; up to the present date the Eureka-Idaho has produced over 17 millions, the Empire and the North Star probably 5 millions each.

The exact information available is very fragmentary; the production by individual mines has been reported in the Mint reports of 1889 to 1892, inclusive, the later reports giving production by county only.

The following data are obtainable for the gold and silver production:

Gold and silver production of the Nevada City and Grass Valley districts.

Year.	Authority.	Grass Valley district, including Deadmans Flat and Forest Springs.	Nevada City district, including Willow Valley.	Total.	Remarks.
1865	J. Ross Browne		$400,000		Quartz mines only.
1866	do	a$2,000,000	a 500,000	$2,500,000	Do.
1870	R. W. Raymond			1,587,000	Do.
1873	do	a 2,000,000	a 67,000	2,067,000	Do.
1874	do			1,089,591	Only principal quartz mines.
1875	do			a 1,500,000	Quartz mines only.
1880	Census	587,260	721,972	1,309,232	Do.
1889	Mint report	1,066,600	448,200	1,514,800	All mines.
1890	do	726,750	566,300	1,293,050	Do.
1891	do	984,500	325,500	1,310,000	Do.
1892	do	781,250	323,800	1,105,050	Do.
1893	do	840,400			Only large quartz mines.

a Approximate.

[1] Nevada County Mining Review, p. 19.

[2] Rept. J. Ross Browne, 1867, p. 37.

The production of Grass Valley is derived almost exclusively from quartz mines. In the Nevada City district the placer mines still contribute a small part of the product.

Accepting Delano's estimate for the earlier years of 80 million dollars for 1849 to 1872, the estimate for the period 1873 to 1893, inclusive, would be about 33 millions, or a total for the districts of about 113 millions, which I am inclined to consider a very conservative amount rather too small. The quartz mines have certainly contributed 60 per cent of this amount, and perhaps more.

It will be seen that the product of Nevada County has remained at an average of 2 million dollars for the last ten years, also that Grass Valley during the past ten years has produced an average of about $850,000 per year, and Nevada City an average of $400,000 per year.

In the above data the gold and silver productions are not separated, the latter being comparatively insignificant. The Mint reports give the production in value, though the estimation of production by weight in ounces would, perhaps, be a better plan. The silver product of Nevada County for 1894 and 1895 is given as about $400, but it is apparent that the production in reality must be larger. Assuming a production of 50,000 ounces of bullion 850 fine and containing 12.5 per cent silver, which probably is below the average, this bullion would contain 6,250 ounces of silver, and as several of the ores contain much more silver, this value is certainly a minimum. The average production is also generally above 50,000 ounces of bullion.

CHAPTER II.

GENERAL GEOLOGY.

GENERAL FEATURES.

The general geologic features of the region here under discussion are delineated and described in the maps of the Gold Belt, especially on the Smartsville and Colfax sheets, and to them the student desirous of more extended knowledge of the Sierra Nevada must be referred. It is, however, desirable to indicate briefly the connection of the districts here described with the general structure of the surrounding country. Throughout the Sierra Nevada there is one sharp geologic distinction to be drawn. It is the difference between the older rocks—the "bed-rock series," as it is usually termed—on the one hand, and the "superjacent series," or the much younger gravels, sands, clays, and volcanic rocks, on the other hand. The bed-rock series consists of highly altered sedimentary rocks, crystalline schists, and older igneous rocks, on which the superjacent series lies in approximately horizontal position. The rocks of the former series have been subjected to repeated orographic disturbances, and to a great extent have been compressed, broken, and crushed by these forces. The rocks which are now at the surface were once below it, probably thousands of feet; successive uplifts and constant erosion have removed the upper parts of the rock masses and exposed those once buried in the foundations of the range. Rightly to understand the geology this fact must be borne in mind.

THE BED-ROCK SERIES.

While it is comparatively easy to unravel the later (Neocene) history of the Sierra Nevada, the same can not be said of the immeasurably longer periods preceding it. They included successive epochs of quiet sedimentation, when the ocean covered the place where the range now rises; several distinct epochs of intense volcanic action, when the lavas built up mountains of igneous masses; and other epochs during which mountain-building forces lifted and crushed together these sedimentary and igneous products. In these compressed and crushed masses occurred enormous abyssal intrusions of coarse-grained granitic rocks. Animal life, on the remains of which we depend for the identification of the sedimentary formations, was unusually scant during the intervals of deposition, or most of the fossils were destroyed during the metamorphism which the rocks have undergone. Many parts of the Sierra Nevada have, indeed, the aspect of pre-Cambrian complexes—the oldest known—though, from the evidence available, it is certain that the rocks of the range in general are of much younger age.

The Nevada City and Grass Valley district is located in the upper foothills, near the line where the old igneous rocks of the foothill region give place to the wide belt of slaty, sedimentary rocks of the middle range; east of this sedimentary belt the granitic rocks of the highest parts of the range begin. High ridges of fine-grained, dark-green rocks, diabases, and augite-porphyrites form the first foothills of the Sierra Nevada in Yuba and Nevada counties. In the latter county these rocks extend to near Anthony House and Indian Springs, where they are replaced by a belt of coarser-grained granitic rocks (granodiorite, diorite, and gabbro), which terminates along a line drawn by French Corral, Rough and Ready, and Wolf Creek Mountain. Eastward of this line, up to Nevada City and Grass Valley, the geology is very complex; relatively narrow belts of more or less metamorphosed sedimentary rocks, standing at steep angles, alternate with large quantities of fresh or metamorphosed igneous rocks. Near Nevada City this complex is separated from the predominantly sedimentary slates to the east by the rounded southern end of the great intrusive granodiorite mass extending more than 20 miles northward into Butte County. In the southern part of Nevada County the diabases and porphyrites of the foothills extend very far eastward, and an area of these rocks reaches northward, including Osborne Hill, to the east of Grass Valley.

The region of complicated structure begins at Rough and Ready, 5 miles west of Grass Valley, with amphibolites and gabbros; then follows a belt, from one-fourth of a mile to 1½ miles wide, of sedimentary clay-slates and siliceous slates, which, near the North Star mine, enters the Grass Valley tract. A branch of these slates is deflected to the southeast and traverses the northeastern part of the Grass Valley tract. Between Grass Valley and the main clay-slate belt lies a body of diabase and porphyrite about three-fourths of a mile wide, the continuation of which northward, though broken for a short distance by intervening slate masses, is found west of Newtown. East of this diabase belt lies the Grass Valley area of granodiorite, 5 miles long, a rather narrow body of coarse-grained granitic rock, the northerly end of which is found in the city of Grass Valley. Eastward of this comes the great porphyrite and diabase area of Osborne Hill, limited again by the above-mentioned streak of sedimentary slates cutting obliquely across the Grass Valley tract.

The greatest complication is found between Nevada City, Newtown, and Grass Valley. Within this area the rocks may be divided into three groups: (1) The two narrow belts of siliceous clay-slates with steep dip, one following the contact of the Nevada City granodiorite area for a long distance, the other embedded in porphyrites one-fourth of a mile eastward. (2) The diabases and porphyrites, occupying a considerable area to the south of Nevada City and continuing down to the vicinity of the Maryland mine. These dark-green, fine-grained

rocks form pointed areas running out northward. The largest, adjoining the first-mentioned slate belt, comes to a point about 3 miles west-northwest of Nevada City. (3) The diorite-gabbro-serpentine complex, beginning north of South Yuba River, forming a lenticular mass 9 miles long and not over 3 miles wide, and running out in several points a short distance east of Grass Valley. The largest part of the latter area consists of a coarse-grained, lighter or darker green diorite or gabbro, or a rock intermediate between the two. In it lie several lenticular masses of serpentine, usually running out to sharp points. The road from Nevada City to Newtown crosses the two largest of these serpentine masses. Less altered pyroxenites and peridotites are found in or near the serpentine. There is excellent reason for believing that all the rocks of this complex are of similar age and origin.

Turning now to the question of the relations of all these different rocks, it should be stated that no fossils have thus far been found in the sedimentary rocks of the district. The greater part of the latter have been referred to the Calaveras formation, which embraces the Paleozoic sedimentary rocks of the Sierra Nevada. Among the Paleozoic rocks the Carboniferous strata doubtless predominate, but the paucity of fossils has permitted identification only at relatively few points. The determination of the rocks in question as "Calaveras," therefore, rests on circumstantial evidence only. These slates of the Calaveras formation are probably the oldest rocks in the district. During a mountain building disturbance toward the end of the Paleozoic or the beginning of the Mesozoic these beds became folded and compressed. This earliest uplift was associated with the outbreak of igneous rocks, which, indeed, in some localities took place even during the deposition of the Carboniferous beds, but of those igneous rocks there is no positive trace in the region under discussion. It is believed that all of the igneous rocks of Grass Valley and Nevada City are post-Carboniferous, and probably none of them antedate the end of the Juratrias period.

During the last portion of the Juratrias period a large part of the Sierra Nevada was a land area. Part of it, however, was submerged, and in that sea the latest sedimentary division of the bed-rock series—the Mariposa beds—was deposited. These are black, carbonaceous clays, interbedded in places with volcanic tuffs, showing that during their formation volcanic forces were acting. In this district a narrow belt of black clay-slates, interstratified with clastic volcanic material, has been determined as belonging to the Mariposa beds.

After the Mariposa epoch followed a time of the most intense mountain-building disturbance, accompanied by the outburst of an enormous quantity of igneous material of different character and texture. The younger sedimentary rocks were folded and compressed and welded with the older series of the same kind, while intrusive masses were

injected in them far below the surface, and volcanoes with thousands of feet of lavas and ash masses were built up on the surface along what are now the foothills of the range. The diabases and the porphyrites belong to this volcanic period, partly as surface flows and dikes, partly as deep-seated intrusive masses, consolidated as coarser granular rocks far below the surface.

Finally, as the last and farthest-reaching phase of that period of igneous activity, came the intrusion of the large granodiorite masses in the then deep-seated part of the range. This took place on so gigantic a scale that the mind strives with difficulty to comprehend the mechanics of the process. Thus, the granodiorites of Nevada City and Grass Valley are the most recent rocks of the bed-rock series. Finally, after the intrusions of the granodiorite, dynamic forces, acting on the mass with different intensity and in different directions, produced fissure systems in which auriferous solutions ascended and deposited their contents. This forming of the mineral veins was the last phase of the Mesozoic revolution in the Sierra.

By no means all of the rocks of the district are now in the same condition in which they were formed. Successive dynamic forces have acted on many of them, producing deformation and schistose structure. Chemical forces have acted on them in at least three distinct ways, changing their mineral constituents until their original form is sometimes scarcely or not at all recognizable—first, as a result and concomitant of dynamic metamorphism; second, by the heat and mineralizing exhalations of the intrusive granodiorite; third, by the action of the hot auriferous solutions on the rocks adjoining the fissures through which they circulated. Often several or all of these effects have been combined in one locality, rendering very difficult the task of unraveling the changes through which the rock has passed. In the region covered by the Smartsville sheet, in which the larger part of the area described in this folio is located, there has been less of that intense dynamic action producing slaty and schistose structure by compression than in some parts of the Gold Belt farther south. One line along which the rocks have been crushed and rendered schistose extends in a northerly direction through nearly the whole region, and passes some distance beyond the western boundary of the Grass Valley tract. As in certain localities along that line the granodiorite has been rendered schistose, it follows that this line of disturbance was produced later than the intrusion of granodiorite. Another line of schistose structure in the Calaveras formation follows the granodiorite contact south and west of Nevada City. But most of the rocks in the area of the special maps are of massive character.

THE SUPERJACENT SERIES.

At the beginning of the Neocene period the Sierra Nevada formed a mountain range of substantially the same outlines as that of to-day,

but of much less height, the summits—located along the same line as the present ones—having an elevation probably of about 5,000 feet, in latitude 38° to 39°. The range had been above water since the end of the Juratrias period, and in its lower part long-continued erosion had reduced it to a hilly, undulating country, frequently broken by high ridges and isolated peaks. A drainage system somewhat similar to the one of the present day had been developed, and auriferous gravels accumulated along the streams from the débris of the numerous quartz veins. The stream receiving the drainage of Grass Valley and Nevada City corresponded closely to the Yuba River, but also embraced the watershed of the upper Bear River. Its southern branch came down from Dutch Flat and You Bet with a northerly direction, crossing Deer Creek at Scotts Flat and the South Yuba at Blue Tent; then turned westward and flowed down to the Great Valley by Badger Hill, North San Juan, French Corral, and Smartsville. During the latter part of the Neocene period volcanic eruptions began near the summit of the Sierra Nevada, and masses of volcanic material began to pour down the river channels. The first material erupted was the light-colored, siliceous rock called rhyolite, which was of comparatively small volume, confining itself as a rule to the river channels. The larger quantity of the eruptives poured out as volcanic muds, which easily found their way down to the foot of the range. On the lower slopes they became mixed with more or less gravel and sand, and their eruptive character is now less apparent. Very heavy flows of this kind found their way down the old South Fork of the Yuba, and part of them flooded a low divide and filled the Nevada City basin. After a short interval, during which considerable erosion took place, the so-called "cement channels" or "channels of the volcanic period" were formed in certain parts of the Sierra, wherever erosion cut through the rhyolitic flows. No such channels have been found in the district here described. Then the period of andesitic eruptions began, and mud flows again poured down from the vents near the divide, at first as dark-colored, fine tuffs and sands, later as a gray or brown tuffaceous breccia, containing, in the foothills as well as in the high range, larger, more or less angular bowlders of the dark-colored porphyritic rock called andesite. These last flows, coming down in rapid succession, flooded everything and covered up the middle slopes to such an extent that only isolated ridges and peaks protruded above them. The whole area here considered was thus once a gently sloping lava field, above which only Banner and Osborne hills protruded. The last of the andesitic flows is supposed to mark the close of the Neocene period. During the volcanic epoch the Sierra Nevada was subjected to a tilting uplift, which at the summit probably amounted to several thousand feet, and the streams at once began the work of cutting into this desolate lava plateau. The directions they took were more generally transverse than formerly. Their similarity to the old drainage was caused

by higher protruding ridges of bed rock, which in many places confined the new river to the old valley. This work of canyon cutting has been continued with ceaseless energy until the present time. Not only has much of the enormous lava masses been washed away, but, owing to the uplift, the rivers have cut down far below the old Neocene bed-rock surface and created the characteristic features of the Sierra Nevada of to-day. These are deep, abrupt canyons separated by broad or narrow ridges of more gently undulating surface.

In the district described in this folio the sloping ridges—Harmony Ridge and the Banner Hill-Towntalk Ridge—are the only remnants of the lava sheet which once covered nearly the whole region, while the present watercourses, here wholly unlike their Neocene predecessors, are sunk several hundred feet below the Neocene surface. Between the close of the andesitic eruptions and the present day occurred the extensive glaciation of the High Sierra, but the glaciers terminated about 30 miles above Nevada City; and it may be stated with certainty that neither in the Neocene nor in the Pleistocene period have any ice streams extended as far down as the latter place.

CHAPTER III.

THE IGNEOUS ROCKS OF THE BED-ROCK SERIES.

GRANODIORITE.

DEFINITION OF ROCK.

Under the name *granodiorite* are included coarsely granular rocks, intruded and consolidated at considerable depths below the surface, having a normal granitic (eu-granitic) structure, and a mineralogical composition of quartz, soda-lime feldspars, orthoclase, hornblende, and nearly always biotite. Titanite and magnetite are always present as accessory constituents. This rock, which in the Sierra Nevada occurs in enormous areas, forms an intermediate group between the quartz-mica-diorites and the granites, being, however, more closely allied to the quartz-mica-diorite than to the granite. Comparison of numerous analyses from various parts of the Sierra Nevada shows that the chemical composition varies between that of a quartz-mica-diorite and a quartz-monzonite (adamellite, banatite, Brögger). Its geological occurrence and in general entirely similar habit preclude the possibility of dividing it into subgroups.

The rock is very characteristic and can not easily be mistaken. The feldspars are generally white; the quartz is not very conspicuous and does not occur in large grains, as in some granites of the high Sierra; the hornblende is dark-green, often in long, rough prisms; the biotite is of the usual dark-brown color. The general effect is a light-grayish color.

Limits of variation and average composition of granodiorite.

	Limits of variation.	Average composition.
	Per cent.	*Per cent*
SiO_2	59 to 68½	65
Al_2O_3	14 to 17	16
Fe_2O_3	1½ to 2½	1.50
FeO	1½ to 4½	3
CaO	3 to 6½	5
MgO	1 to [a] 2½	2
K_2O	[b] 1 to 3½	2.25
Na_2O	2½ to 4½	3.50
Remainder	....	1.75
		100

[a] Three and one half, one analysis.
[b] Certain masses in the foothills go below 1 per cent.

NEVADA CITY AREA.

Extent and character of surface.— The Nevada City granodiorite area forms the southern end of a great massif extending northward far up in Butte County. It is generally sharply defined in this region, but in its northern part more basic diorites and gabbros are intimately connected with it by transition.

The rock occupies a large part of the area covered by the Banner Hill and Nevada City sheets. It forms a series of rounded, comparatively gently sloping hills with elevations gradually increasing eastward. Deer Creek crosses the area in a canyon which, south of Willow Valley, near the contact with the sedimentary area, has precipitous and narrow slopes and is over 700 feet deep. In the western course it has more gently sloping sides, the inclination rarely exceeding 12°; a steeper slope is, however, usually noted immediately at the creek, in places forming almost a "canyon within a valley." Little Deer Creek cuts a smaller canyon in the granodiorite farther south.

From Nevada City to the Providence mine the canyon, cut in less disintegrated rock than farther east, is narrow and rocky. The western and southern part of the area is rather gently hilly and undulating, but is cut near Deer Creek by steep ravines.

Macroscopical description.—The normal granodiorite is a fresh, coarsely granular rock of light-grayish color, composed of dark-green hornblende, dark-brown biotite, colorless quartz, and white or slightly yellowish feldspar. The grains average about 2 or 3 mm. in diameter. The hornblende is relatively more abundant than the biotite; both of them sometimes occur in idiomorphic form, the hornblende as thick prisms up to 10 mm. in length, the mica as hexagonal foils up to 3 or 4 mm. in diameter. Small grains of yellow titanite are sometimes noticeable. Pyrite is, on the whole, rare, and occurs only in small grains connected with the hornblende. Copper pyrites have also been noticed in the hornblende, but pyrrhotite does not seem to occur. Near the contacts the hornblende sometimes, though by no means always, increases, giving the rock a more basic aspect. Such is the rock along the contact from Deer Creek northward, and also in the vicinity of the North Banner mine, where it should more properly be called a diorite. The dark spots so frequently seen in granitic rocks abound in certain parts of the area, and are composed principally of feldspar and hornblende; they often show fissures and breaks filled with granodiorite. On the whole, the granodiorite shows but slight variation in the different parts of the area. The outcrops of the less decomposed rock are smooth and rounded.

Microscopical description.—In thin sections the fresh, unaltered character of the rock, compared with others of the district, is very striking. The character is comparatively uniform. The mica is normal, dark-brown biotite, with small though distinct angle between the optical

axes; the color is a clear yellowish-brown, without any shade of red. It is sometimes idiomorphic. Local alteration has in places converted some of it to chlorite or muscovite, both appearing as inserted parallel plates. Small fragments of a doubtful mineral are in one slide intergrown with the biotite, showing blue and yellow pleochroism and an extinction of about 45°. The hornblende is green or brownish-green and compact, sometimes roughly idiomorphic and with a maximum extinction of 18° to 20°; occasionally a little chlorite and epidote accompanies it. The hornblende sometimes incloses foils of biotite, but is also occasionally surrounded by biotite. In one specimen 300 feet from the contact in Deer Creek the hornblende shows sharply defined kernels of augite.

The predominating feldspar is plagioclase, forming usually roughly idiomorphic prisms with strong twin-striation and comparatively low symmetrical extinction, hardly ever above 20°. A zonal structure is not common. A micaceous mineral occurs in some as products of incipient decomposition.

The orthoclase is less abundant and occurs as irregular grains; it sometimes contains a slight microperthitic intergrowth of albite; rarely some grains show a very fine and indistinct striation, suggesting the presence of anorthoclase. Microcline does not appear to be present. The quartz forms irregular grains; undulous extinction is seldom noticeable, nor is there on the whole much evidence of strong dynamic action on the rock.

Of accessory minerals, magnetite in irregular, often rounded grains is always present and mostly contained in the hornblende or in the biotite. Iron pyrite is sometimes seen; it is never beyond doubt primary, but always appears associated with the decomposition products of the hornblende. Titanite is quite common, as well as apatite and zircon. The structure is characteristically hypidiomorphic; the mica and hornblende are sometimes, the plagioclase nearly always, partly idiomorphic; these minerals are cemented, so to speak, by a later consolidated mass of orthoclase and quartz. This structure is always characteristic of the granodiorite. Small crystals of plagioclase are occasionally embedded in the mica or in the hornblende. In some specimens a very fine grained micro-pegmatitic intergrowth of quartz and plagioclase is noted as a rim surrounding the end of some of the feldspar crystals.

An important characteristic of the granodiorite is its fresh character, owing to an absence of dynamical and chemical alteration.

The dark spots occurring so frequently, for instance at the quarry at the west edge of the Banner Hill sheet, consist mainly of hornblende (with a little mica) and idiomorphic plagioclase, between the prisms of which lies a little quartz. They also contain much magnetite, and a grain of probably primary pyrite was once noted.

Chemical composition.—A fresh specimen taken near Shurtleff's barn, about 1 mile southeast from Nevada City, analyzed by Dr. W. F. Hillebrand, gave the following result:

Analysis of granodiorite from near Nevada City.

	Per cent.
SiO_2	66.65
TiO_2	.38
Al_2O_3	16.15
Fe_2O_3	1.52
FeO	2.36
MnO	.10
CaO	4.53
SrO	Trace.
BaO	.07
MgO	1.74
K_2O	2.65
Na_2O	3.40
Li_2O	Trace.
H_2O below 110°	.18
H_2O above 110°	.72
P_2O_5	.10
FeS_2	.02
	100.57

The analysis is typical of the granodiorite. The relatively low percentage of MgO (FeO, Fe_2O_3) and CaO is characteristic, as is the fact that the sum of the alkalis exceeds considerably the lime. The TiO_2 is present chiefly as titanite. In view of the fact that the exact composition of the hornblende and mica is unknown, there are not sufficient data for the calculation of the constituents of the rock. The rock contains in estimate:

	Per cent.
$K\,Al\,Si_3O_8$	15
$Na\,Al\,Si_3O_8$	29
$Ca\,Al_2\,Si_2O_8$	15
Hornblende and biotite	16
Quartz	22
Apatite	.24
Magnetite	1.50
Titanite	1
	99.75

The plagioclase is consequently an oligoclase. It should be remarked that the relation between the potassa and the soda is by no means constant. In a specimen from the same area, taken where the Purdons Bridge road crosses Rock Creek, 4 miles north of Nevada City, a partial analysis by W. H. Melville gave 0.89 per cent K_2O and 4.25 per cent Na_2O.

Weathering.—Except along the bottom of the deeper creeks, the granodiorite is very soft and decomposed; in places the decomposition reaches a depth of 200 feet. Especially is this the case in the eastern part of the area, which is covered by a deep dark-red soil in which few remaining harder bowlders lie scattered. This is a true residual soil, derived from decomposition in place, and reaches its greatest depth on the northern slope of the ridges. Beautiful exposures of this decomposition are seen in the hydraulic pits southeast of Canada Hill. The decomposition of the granodiorite seems to have at least two distinct stages. The first consists in loosening the grains to a soft crumbling aggregate. This loosening seems to be due mainly to the decomposition of the feldspar grains. The biotite and hornblende are not much altered. Such is the condition of the rock in the lower foothills. The second stage consists in the complete decomposition of the hornblende and biotite as well as the feldspar. Next to the quartz, the biotite is the most resistant mineral. The ferrous oxides are completely converted into ferric, and the result is a soft, clayey, deep-red material.

In the western part of the area most of the residual soil covering the ground has been swept away; coarse, crumbling, and yellowish rock very frequently comes to the surface, and harder masses frequently show their light-gray, round outcrops through the more decomposed surrounding rock. This peculiar manner of decomposition is well shown in several places. The harder masses are often surrounded by concentric softer shells, as seen near the railroad station at Nevada City. Excellent exposures of very hard, rounded outcrops in predominantly soft rock are seen on the bed rock of the hydraulic diggings half a mile northwest of Nevada City, and similar sharply defined hard masses, usually called "bowlders," are often found in driving tunnels through the soft decomposed granodiorite to reach the Tertiary channels.

Relation to surrounding rocks.—The granodiorite is the youngest member of the fundamental series, little affected by mechanical and chemical changes. It was evidently intruded far below the surface as immense masses or batholites of molten magma, which slowly consolidated and which a long-continued erosion finally exposed. The rocks near the contacts, chiefly the sedimentary rocks, show a most decided and characteristic contact metamorphism, produced by the heat and emanations of the eruption. The contacts are not generally well exposed, on account of the surface decomposition; good exposures are, however, found on both sides of the massif in Deer Creek.

Dikes of granodiorite occur sparingly in the adjoining sedimentary rocks. One, about 20 feet wide, was noted in the bed of Deer Creek, 80 feet east of the contact; this rock is a normal granodiorite, containing fragments of the sedimentary metamorphic rocks through which it breaks out. In the Federal Loan mine, dikes of dark diorite, with large hornblende crystals, break through the sedimentary rocks; these diorites, which contain some pyrite and pyrrhotite, are probably genetically connected with the granodiorite. At the ditch 400 feet above and southeast of the mine the granodiorite sends out dikes or apophyses of somewhat darker dioritic character. A great number of dikes or smaller intrusive masses are noted above the North Banner mine at the head of Little Deer Creek; these consist of usually rather dark granodiorite or quartz-mica diorite.

A small, apparently intrusive mass on the Scotts Flat road at the divide north of the Federal Loan, and the small dike nearest to the head of Little Deer Creek, have been indicated as diorite on the map. They present, however, some peculiar features, and show great similarity with a rock collected at the extreme edge of the Banner Hill tract, on the road east southeast of Banner Hill. It is believed that these rocks should rather be referred to the later series of diabases and porphyrites, which frequently carry hornblende.

An excellent instance of a small branching dike of granodiorite is seen on the south bank of Deer Creek below the Providence mill; other dikes occur along the road, just south of the same mill and on the south bank of Deer Creek 400 feet west of it. Intrusive masses of granodiorite in altered diabase are also seen in the Providence mine on the sixth level, on the contact vein, and on the third level of the Nevada City mine in the second crosscut in the foot wall south from the new shaft.

Dioritic facies.—In the vicinity of the North Banner mine the granodiorite becomes more basic and similar to a diorite. At the contact a few hundred feet southwest of the mine it also assumes a finer grain. The small area northeast of the mine inclosed between the andesitic breccia and the sedimentary rocks is a rather dark quartz-mica-diorite. In the area west of the mine, separated from the former by a projecting tongue of slate, the rock is more clearly dioritic and consists of plagioclase and brownish-green hornblende, one of the latter showing a kernel of augite. A little quartz separates the lath-shaped feldspar crystals.

Diorite and granodiorite northwest of the Nevada City mine.—Near the contacts the granodiorite has sometimes, as noted, a tendency toward more basic development, but no extensive change of this kind occurs until beyond the Nevada City mine. From Birchville, 6 miles to the northwest, to the Nevada City mine the granodiorite is adjoined by an area of diorite, with associated gabbros and pyroxenites. At the excellent exposures in Shady Creek, about 2½ miles east-northeast of French Corral, the contact between diorite and granodiorite is clear and

sharp, the latter being younger and intrusive into the former. Again, in the canyon of the South Yuba the contact between the two formations is sharp, though it appears to be a fault plane dipping east; but from the river to the Nevada City mine the relations are doubtful. Along a line running due northwest from the mine the granodiorite becomes darker, and changes imperceptibly into dark diorite and gabbro, replaced by pyroxenite at the edge of the Nevada City tract. Thus there is along this line no distinct contact line to be drawn between the granodiorite on one hand and the diorite-gabbro-pyroxenite complex on the other. This is puzzling, for all the other evidence is in favor of the latter being distinctly older than the granodiorites; besides, it contains dikes of the diabase-porphyrite series, which, on the other hand, is distinctly older than the granodiorite. There may, after all, be a contact, although the similarity of the formations and the decomposition of the surface prevent its being noticed.

The diorite dikes near Indian Flat.—In the belt of the schistose greenstones from 1,000 to 2,000 feet west of the granodiorite contact there are two long-drawn bodies of diorite which appear to be intrusive masses; they probably are connected with the granodiorite in origin, and form a facies or product of differentiation of that magma. The rock is dark and coarse, and composed of dark-green uralitic-appearing hornblende and white or greenish feldspar. In thin section large grains of green hornblende and partly idiomorphic plagioclase form the chief constituents. There is much apatite and ilmenite. Some of the hornblende may have been derived from a primary pyroxene, but of this there is no direct proof. A little secondary biotite is noticed in the hornblende.

GRASS VALLEY AREA.

Extent and character of surface.—The granodiorite of Grass Valley forms an elongated area much smaller than that of Nevada City, and extending along Wolf Creek for 5 miles south of Grass Valley. Its width varies from less than half a mile up to nearly 2 miles. A series of rounded hills marks the area on both sides of the more abrupt canyon of Wolf Creek. Compared with the great mass of Osborne Hill, the area marks a depression of old Tertiary date, produced by the more easily disintegrating character of the rock.

Rock description.—The Grass Valley granodiorite differs somewhat in appearance from that of Nevada City. It is a greenish-gray, medium-grained rock, consisting of two kinds of feldspar—pale-red and greenish—black hornblende, and quartz. Only exceptionally, as at the Scotia shaft, does biotite enter into the composition. Small grains of pyrite are not uncommon. The type is practically constant over the whole area.

Under the microscope the plagioclase is rather predominant, usually partly idiomorphic, and often filled with micaceous minerals. The

orthoclase hardly ever shows crystal outlines, and is generally fresher than the plagioclase. The quartz is sometimes intergrown with the orthoclase in micropegmatitic structure. Microperthite is also noted, and occasionally a very finely striated feldspar associated with the orthoclase, possibly anorthoclase. The hornblende is the ordinary granitic variety with brownish-green color, frequently converted into chlorite and epidote. Accessories are magnetite, titanite, zircon, and apatite. The first-mentioned mineral is probably somewhat titaniferous, for leucoxene (titanite) has been observed to form from it. Small grains and crystals of pyrite frequently occur, but are probably all secondary. They are closely associated with the hornblende and sometimes surrounded by a chlorite rim.

The structure is typically hypidiomorphic, imperfect prisms of plagioclase and hornblende being partly embedded in orthoclase and much quartz.

The rock on the whole is somewhat less fresh than the granodiorite of Nevada City. Darker dioritic modifications of the rock are rare, but were noted in the branch of the area found 1¼ miles west of Grass Valley.

Composition.—The analysis by Dr. W. F. Hillebrand of an apparently fresh specimen from Kate Hayes Hill, near the Hecla shaft, gave:

Analysis of Grass Valley diorite.

	Per cent.
SiO_2	63.85
TiO_2	.58
Al_2O_3	15.84
Fe_2O_3	1.91
FeO	2.75
MnO	.07
CaO	4.76
SrO	Trace.
BaO	.06
MgO	2.07
K_2O	3.08
Na_2O	3.29
Li_2O	Trace.
H_2O below 110° C	.28
H_2O above 110° C	1.65
FeS_2	.04
P_2O_5	.13
Total	100.36

The comparatively simple composition renders a calculation of this analysis possible, under the well-founded supposition that the hornblende is of the ordinary aluminous character.

		Per cent.
SiO_2	11.6	
Al_2O_3	3.3	
K_2O	3.1	
$KaAlSi_3O_8$		18
SiO_2	19.2	
Al_2O_3	5.5	
Na_2O	3.3	
$NaAlSi_3O_8$ (*a*)		28
SiO_2	5.3	
Al_2O_3	4.4	
CaO	2.4	
$CaAl_2Si_2O_8$ (*b*)		12.1
SiO_2	6.7	
FeO Fe_2O_3	3.2	
Al_2O_3	2.6	
MgO	2.1	
CaO	2	
Hornblende		16.6
Quartz		20.8
Magnetite (estimated)		1.5
Titanite		1.4
Apatite		.3
Total		98.7

a and *b* = Ab_7An_3, 40.1 per cent.

The hornblende would then have the following approximate composition:

	Per cent.
SiO_2	40.3
Al_2O_3	15.7
Fe_2O_3 FeO	19.3
CaO	12.1
MgO	12.6
Total	100

The plagioclase has the composition of an oligoclase, which corresponds with the microscopic investigation.

It is evident that there is considerable variation in the alkalis, for a partial analysis of the rock from Allison's ranch, rather rich in hornblende, by W. H. Melville, gave 6.16 per cent CaO, 0.53 K_2O, 3.74 Na_2O, probably corresponding to 30 per cent Ab, 15 per cent An, and 3 per cent Or, or a normal quartz diorite.

Weathering.—Though similar to the Nevada City rock in composition and grain, it develops a considerably greater resistance to weathering. It forms light-colored, rounded outcrops, but less characteristic than those of Nevada City; nor does the disintegration extend down so deep by far as in the Nevada City area. The extreme result of weathering is a deep-red clayey soil, a few feet deep.

Relation to surrounding rocks.—While the granodiorite is singularly free from dikes and intrusive masses, dikes of it occur in the surrounding rocks, showing its more recent age. The contacts are satisfactory only at isolated places, on account of extensive weathering, but whenever well exposed are sharp and distinct. On the north the granodiorite borders against the sedimentary rocks with distinct, though not wide, contact-metamorphic zone. A dike-like mass of granodiorite with unsatisfactory exposures is contained in the sedimentary series one-half mile west of the railroad station. The contact with the siliceous chert in the southwest part of the area is very poorly exposed, but does not give the impression of very intense contact metamorphism.

The diabase and porphyrite near the contact are not appreciably altered by the granodiorite, as fresh diabase occurs close up to or immediately at the contact. Dikes of granodiorite in the latter rock were noted at the old Peabody shaft, in Wolf Creek, a little above the Granite Hill mine, in the tunnel 800 feet south of Central North Star shaft, in an outcrop in the swampy meadow 2,300 feet south of North Star shaft, and less well exposed at several points along the contact south of the W. Y. O. D. mine.

APLITE.

Definition.—Aplite is here used to designate granular to fine-granular acid rocks, chiefly consisting of alkali feldspar and quartz, and usually occurring as dikes or dike-like masses in or near the larger bodies of granitic rocks.

Occurrences and description.—A small, 10-inch-wide vein of coarse pegmatite crops out along the road 200 feet north of the Mountaineer mine. On the Excelsior ditch, about 1 mile above Jones Bar and about 4 miles from Nevada City, there is, in granodiorite, a dike 3 to 4 feet wide, of a medium-grained white or yellowish rock, consisting of feldspar and quartz, with a very little brown mica. This rock (220 N. C.) contains 1.06 per cent CaO, 5.57 K_2O, and 3.43 Na_2O, according to a partial analysis by Mr. George Steiger, and is thus a granitic dike rock with predominating alkali feldspars.

In the northwestern part of the Nevada City tract there is, in diorite, a large mass of this rock running out in numerous branching dikes. These little dikes, intruded in the dark amphibolitic rock, are well exposed where Rock Creek crosses the eastern limit of the aplite. The rock is almost white, medium-grained, of a sugary texture, and contains only a few small grains of biotite or hornblende. At the southern end of the area it has a somewhat schistose or pressed appearance. The rocks of this area have been subjected to dynamic action, possibly a direct result of the strains during the formation of the vein fissures, and though schistose structure is not always visible, the microscope reveals its crushed condition. It is essentially a nearly allotriomorphic, interlaced, granular aggregate of quartz and feldspar, except for a few scattered foils of brown mica and grains of epidote. The quartz grains are usually crushed and pressed out to long-drawn aggregates; the feldspar grains show this to a smaller extent. Between the larger feldspar grains there are many small ones, occasionally with micropegmatitic structure, and sometimes giving the impression of having been produced by peripheral crushing. Microperthitic intergrowths are extremely common; there is also some microcline. A few of the grains show distinct twin lamellæ, but some grains otherwise resembling orthoclase have an extremely fine and hardly visible striation in one direction and may be anorthoclase. A partial analysis of No. 159 N. C. by Mr. H. W. Stokes gave 77.05 per cent SiO_2, 0.73 CaO, 5.06 K_2O, and 3.43 Na_2O. The close agreement with the rock from Excelsior ditch should be noted. The aplite dike, 200 feet above the Champion mill, is very similar to the rock just described, though not quite so much pressed.

GRANITE-PORPHYRY.[1]

Definition.—The granite-porphyries are holocrystalline, porphyritic dike rocks, rich in free silica and characterized by the prevalence of alkali feldspars.

Occurrence and description.—Certain rocks occurring as dikes in the diabase near the granodiorite contact, chiefly in the vicinity of the Omaha mine, Grass Valley tract, belong to this group. The sometimes very fine grained groundmass caused them to be laid down on the map as quartz-porphyries; but as they are true dike rocks, closely connected with granitic intrusions, the name "granite-porphyry" is more appropriate. These rocks differ only structurally from the aplites.

The granite-porphyries are chiefly yellowish-gray or gray, fine-grained or flinty rocks, indistinctly porphyritic by small feldspar or quartz crystals ranging up to 3 mm. in size. Small foils of biotite are sometimes present.

Microscopically, several types are present. No. 113 G. V., from the principal area, contains idiomorphic, short and thick feldspar crystals, at least half of them with twin striation. Phenocrysts of clear quartz

[1] Quartz-porphyry on map.

with corroded outlines are present. White mica and some epidote has formed in the feldspars. The biotite foils are converted into epidote-chlorite aggregates.

The groundmass is microcrystalline, of interlocking grains of quartz and unstriated feldspar; also some with twin striation. In places the groundmass shows micropegmatitic intergrowth, approaching spherulitic forms. Small foils of biotite occur in the groundmass.

A partial analysis by Mr. George Steiger gave—

	Per cent.
SiO_2	75.45
CaO	.69
K_2O	4.56
Na_2O	3.53

or practically equal quantities of Or and Ab.

Another rock from a smaller dike (109 G.V.) is yellowish-gray, fine-grained, but not flinty. Under the microscope it is a spherulitic aggregate of feldspar and quartz, the spherulites ranging from an intimate micropegmatitic intergrowth to typical radial aggregates, showing the black cross between crossed nicols. The groundmass between the spherulites is fine-grained, allotriomorphic, partly also micropegmatitic.

A partial analysis by Mr. George Steiger gave—

	Per cent.
CaO	0.60
K_2O	4.21
Na_2O	3.20

showing this rock to be practically identical with the one first described. SiO_2 was not determined, but the rock is very acid.

A third type, a dike in diabase from the fourteenth level of the Omaha mine, near the shaft, is grayish, flinty, and shows small feldspar crystals. Under the microscope the feldspar phenocrysts are very much filled with micaceous aggregates, clouding them completely. The groundmass is a clear allotriomorphic aggregate of quartz and unstriated feldspar, easily resolved by objective No. 7 (Hartnack).

Similar rocks are also found in the diabase near the contact in the W. Y. O. D. mine. White dikes, either quartz-porphyries or aplites, are those on Little Wolf Creek, 660 feet south-southeast of the Golden Treasure shaft and in the new Peabody shaft. Both of these contain abundant pyrite, possibly introduced by the vein solutions.

DIORITE-PORPHYRITE.

Occurrences and description.—The granodiorite being the latest principal member of the fundamental series, very few dikes of any kind are found in it. The aplites have already been mentioned, and the granite-porphyries in all probability are also later, though not found in the granodiorite. In three places basic dark-green porphyritic rocks have also been found as dikes in granodiorite. There may be more occurrences of the same rock as dikes in other parts of the fundamental series, but if not prominent they would easily be overlooked, as they present great similarity to the ordinary hornblende-porphyrites.

The best exposure, to which Mr. George A. Treadwell called my attention, is in the canyon of the South Yuba River, 800 feet below the Excelsior dam, about northwest of Nevada City and 2 miles outside of the special sheets. At this place there are two dikes 16 inches wide in the normal granodiorite, only a few feet apart; both dip 30° W., and many fissures and joints with the same dip are seen in the vicinity. The rock is dark-green and dense, with many small feldspar crystals and abundant acicular black hornblende. In thin section the rock is seen to be holocrystalline porphyritic; the larger feldspar crystals are not over 1 mm. long, while the needle-shaped hornblende may reach 2 or 3 mm. The former are sharply idiomorphic and show twin striation; the latter pale greenish-brown in color and with normal extinction. The groundmass is composed of microlites and grains of the same hornblende, and apparently also the same plagioclase, as there are all transitions between the phenocrysts and the microlites in the groundmass. Magnetite is rather abundant. According to a determination by Mr. George Steiger, the rock contains 60.85 per cent SiO_2. The rock shows plainly the character of the lamprophyric dike rocks, and is closely related to the camptonites, though not so basic. Such dike rocks have been found, though not abundantly, in various parts of the Sierra Nevada, and are apparently always later than the granodiorite.[1] They often appear parallel to the gold-quartz veins, and have evidently been injected a short time previous to the formation of the latter. Two localities have been found in the Banner Hill tract, but in both cases the rocks are so altered as to be scarcely recognizable. The first is a dark grayish-green rock found on the dump of the Independence shaft (Murchie mine), and is said to have come from a dike running parallel to the vein, which dips W. 36°. In thin section it is seen to be a very much altered porphyritic rock, with long, slender hornblende needles, now entirely converted to calcite. The second occurrence forms a 3-foot-wide dike in the Alpine tunnel, forming the hanging of the St. Louis vein. The rock has much the same extremely decomposed appearance as that from the former locality, and shows small hornblende prisms in a groundmass of fine felted mixture of feldspar microlites and acicular hornblende.

[1] Compare The gold-silver veins of Ophir, Cal.: Fourteenth Ann. Rept. U. S. Geol. Survey, p. 262.

THE DIORITE-GABBRO-PERIDOTITE GROUP.

The rocks of this series, embracing diorite, gabbro, hornblende rock, pyroxenite, peridotite, and serpentine, form a series so intimately connected by transitions that there can be no doubt of its close genetic relationship; nor is it possible to strictly separate the rocks in the description.

DEFINITIONS.

Under *diorites* are here included the coarse-granular, abyssal rocks with normal granitic structure, composed chiefly of soda-lime feldspars of medium acidity and hornblende; biotite or pyroxene may sometimes replace the hornblende. The granodiorites, an intermediate group ranging from quartz-diorite to quartz-monzonite (Brögger), have already been separated. With the granodiorite has been included several smaller masses and dikes, which probably are only local products of differentiation of the granodiorite magma. The diorites have a silica percentage varying between 51 per cent and 58 per cent. The lime is considerably in excess of the sum of the alkalis, the reverse being true of the granodiorites. A considerable percentage of ferromagnesian silicates is usually present.

The *gabbros*, as here defined, include similar rocks with basic feldspars (labradorite or anorthite); the ferromagnesian silicates may be either pyroxene, hornblende, or mica.

The *pyroxenites* are coarse-granular, very basic rocks of granitic structure composed chiefly of pyroxene, with very small amounts of feldspar.

The *peridotites* are similar rocks composed of olivine and a pyroxene or an amphibole.

The *serpentines* are secondary rocks, consisting chiefly of serpentine, with minor quantities of residuary minerals or newly formed actinolite. They are evidently derived from gabbros, pyroxenites, and peridotites, chiefly from the latter two. It will be shown later that they may also be derived from certain porphyrites. The action producing the serpentines is not weathering, but must be regarded as similar to the actions effecting metamorphic alterations.

Referring to the Smartsville folio, it will be seen that a double wedge-shaped area, determined as gabbro-diorite with masses of pyroxenite, peridotite, and serpentine, extends from Birchville to a point east of Grass Valley, adjoining the granodiorite and diabase on the east and the diabase and sedimentary rocks on the west. The name *gabbro-diorite* was adopted as a convenient expression to include different rocks belonging to the diorite and the gabbro families. It would no doubt have been better to designate this mixture of rocks gabbro *and* diorite. The area is one of great complexity, with gradual transitions between the gabbros, diorites, and pyroxenites, while the serpentines are more sharply defined. In the northern part of the large area great

complexity is added by the fact that the whole has been subjected to more or less intense dynamometamorphism. Several parts of this area fall within the space of the detailed sheets.

THE ORO FINO DIORITE-PYROXENITE AREA.

Reference has already been made to this area in the northwest part of the Nevada City tract while discussing its indistinct contact with the granodiorite.

The southern part of the area, running out in the shape of a wedge, contains chiefly diorites of dark color and average granular texture, weathering less easily than the granodiorite, forming rougher outcrops and a scant, deep-red soil.

Under the microscope the rocks are shown to be diorites with very little biotite and a little quartz, the latter often included in the hornblende. There is very little pyrite in the rock. Near the Kirkham mine the diorite contains many small pegmatite veins.

At the northwestern end of the big aplite dike the rock has changed to a dark-green, coarse-granular pyroxenite, consisting chiefly of large irregular grains of a partly uralitized pyroxene (diallage?), with some grains of apparently primary greenish-brown hornblende with augite kernels. Between the pyroxene grains lie small grains of a feldspar, largely converted into micaceous aggregates.

Small dikes of aplitic rocks are found in the pyroxenite. In other places close by (800 feet northwest of Coan's mine) there is a larger amount of anorthite with broad twin lamellæ and appropriate extinctions; consequently the rock is here a gabbro.

Still farther north, 2,400 feet north of Coan's mine, the coarse-grained, dark rock consists of partly uralitized augite, greenish-brown hornblende, biotite, and triclinic feldspar, with a little quartz and probably also some orthoclase. There is also magnetite (ilmenite?) and much apatite.

Still farther northwest, at the Oro Fino mine, dark, coarse-granular rocks appear which are intermediate between diorite and gabbro. The specimen, from the dump of the mine, is somewhat decomposed and affected by pressure, many of the feldspar lamellæ being curved and bent. It consists of an apparently not very basic plagioclase, augite, and biotite; probably also some orthoclase and quartz.

THE PLEASANT FLAT DIORITE AREA.

Description of rock.—This area, extending on both sides of Deer Creek, at the western limit of the special map is predominantly composed of a fairly normal diorite of coarse texture and dark-green color, containing a large amount of hornblende. Seen in thin section, the hornblende is brownish-green, partly anhedral, partly roughly prismatic; the feldspar is lath-shaped or anhedral with twin lamellæ, the extinc-

tions of which indicate a medium basicity. A little quartz is sometimes found between the grains. The sericitic alteration has proceeded far, as a rule; much of the hornblende is also converted to uralite, chlorite, and epidote. On the whole, there is much more of these secondary minerals than in the granodiorite. Grains of pyrite are scarce and usually associated with epidote; in some cases they might possibly be primary.

A partial analysis of a typical specimen, by Dr. Peter Fireman, gave:

	Per cent.
SiO_2	51.24
CaO	7.97
K_2O	.93
Na_2O	3.44

Of the CaO, at least 2 per cent, probably 3 per cent, must be contained in the hornblende. (Compare calculation of Grass Valley granodiorite.) There would thus be not more than 30 per cent An and 27 per cent Ab, which shows that the feldspars are only of medium basicity.

Facies of the rock.—In many places the rock is subject to changes in grain and composition, some parts of it being richer in hornblende, while in some parts the feldspar acquires more prominence and some quartz begins to appear. At Carls tunnel, near the andesite contact, the rock on the dump exhibits a very coarse pegmatitic structure, and consists of uralite crystals several inches long in a white, partly saussuritic mass, with sp. gr. 2.98. To the northward, beyond the special maps, the rock gradually changes to a typical light-colored gabbro, and even in this area there is undoubtedly a certain relationship with the gabbro occasionally exhibited.

Weathering.—Deep, rich, residual soil produced by weathering occurs south of Deer Creek, and especially near the andesite contact. On the north side the soil is less deep, but the rock is disintegrated and crumbling.

Relation to surrounding rocks.—Toward the north and east the diorite is in contact with serpentine and peridotite, with a rather sharply defined contact. Tongues of serpentine extend into the diorite, as shown on the map. The area contains an extensive system of dikes of uralite-diabase, which will be described later.

THE FAIR-GROUND AREA OF DIORITE.

Description.—This is really the continuation of the above-described area, emerging from below the southern edge of the covering andesitic tuff. The character of the rock is also entirely similar, being a coarse, dark diorite. There is in some places also the same frequent and rapid change of grain and basicity. The rock is deeply decomposed on the hill northwest of the Fair-grounds.

Relation to other rocks.—Toward the northeast the contact with the dark-green porphyrites is in places very indefinite and not well exposed, much apparently brecciated material occurring along it. The coarse diorite contains fragments of darker greenstones of finer grain. Along the north side of the race-track there is a considerable amount of this mixed material. The contact with the serpentine is fairly sharp.

DIORITE AREAS IN THE SERPENTINE.

Smaller masses of diorite, irregular or lens-shaped, occur in the serpentine. The largest one, north of the Idaho mine, is substantially like the Fair-ground area, and contains besides some dikes of a hornblendic porphyrite.

In the Indian Flat serpentine area irregular masses of diorite are frequent, and probably represent dioritic variations of the prevailing peridotite-pyroxenite magma. In the extension of the Idaho serpentine area northwest beyond the special sheets, on the Newtown road, smaller masses of dark-green, coarse-granular *hornblende rock* is found, evidently corresponding to the pyroxenites, and consisting almost exclusively of primary, deep brownish-green hornblende with strong pleochroism. No larger areas of this hornblende rock are found. It should not be confounded with the amphibolites, which, as here defined, include only the dynamo-metamorphic rocks in which the hornblende is secondary.

THE MOREHOUSE DIORITE DIKE.

This dike-like body is contained in serpentine and gabbro half a mile west of the Maryland mine. It is a medium-grained, grayish-green rock, containing, besides feldspar and hornblende, much pyrrhotite in small grains. Under the microscope the rock consists of the usual dioritic hornblende in irregular grains, lath-like or irregular feldspar with narrow striations, with smaller residual masses of orthoclase and quartz and a little magnetite. The structure is typically hypidiomorphic. There is much chlorite with the hornblende, and micaceous products with the feldspar. The pyrrhotite is generally of secondary origin, occurring chiefly with the chlorite.

GABBRO AREAS.

General features.—Typical gabbros do not form extensive areas in this vicinity; most of the areas occurring as elongated masses in the serpentine probably represent, as does the diorite in similar occurrence, facies of the prevailing pyroxenic or peridotic mother rock of the serpentine.

Gabbro dikes below the Providence mine.—In the dike-like masses on both sides of the serpentine below the Providence mine the gabbro is very coarse grained, consisting of uralitic pyroxene of light-green color and whitish feldspar, very often with a tinge of brown. The grains average about 5 mm. In weathering, the large outcrops assume a whitish color. Microscopically, the feldspars show large anhedral grains with broad striation, the striations indicating a composition

between bytownite and anorthite. The diallage is almost wholly converted into uralite, fibers of which are also found in the feldspars. The latter are in part clouded by micaceous products. Some ilmenite is also present, as well as some finely distributed pyrite, the latter probably secondary.

Gabbro in the Maryland serpentine.—There are several smaller areas of gabbro in the Maryland serpentine, one of which is indicated on the map. The rock is only in part typical, some of it being schistose and dynamo-metamorphosed. Up toward Jones Bar, in the continuation of the diorite-gabbro series of the special sheets, there are large areas of gabbro similar to the one here described and also characterized by the whitish color of the outcrops; it is here frequently dynamo-metamorphosed, producing light-colored actinolite schists, often also with much zoisite.

The Maryland gabbro.—The Maryland gabbro area is the largest one found on the area of the special sheets, extending from South Wolf Creek up to the Maryland mine. The rock is in the main similar to the one just described; it is coarse-grained, of a prevailing light-green color, and is composed of uralite-diallage and a basic plagioclase.

The exposures are very poor, the deep disintegration of the rock rendering it difficult to decide the relations with the surrounding rock. It borders, with a fairly distinct contact, on the serpentine, smaller masses and seams of the latter rock occurring in the gabbro. Toward the east the contact with the coarser diabases of the Maryland area is very obscure; abundant dikes of diabase, extending from the main area, appear to be contained in the gabbro, but in the area laid down as diabase there is also, as at South Idaho, more or less gabbro traversed by dikes of the darker rock. The best exposures are along the railroad near the sulphuret works, but they are very unsatisfactory; the gabbro disintegrates easily to a crumbling mass, while the hard diabase dikes remain intact, their fragments covering the ground.

The East Maryland gabbro.—Half a mile east of the Maryland mine another gabbro area begins. This is practically included in serpentine, and the rock varies a great deal in composition. While the prevailing rock is the normal, coarse, whitish gabbro, there is also much of darker diabasic and amphibolitic rocks, the relation of which to the gabbro is obscure on account of poor exposures. On the dump of the Chevannes tunnel much saussurite or saussuritic gabbro was found.

A little gabbro is also found in the Mariposa slates at the south end of the small serpentine area near the Washington mine (6,500 feet east of the Maryland mine).

THE INDIAN FLAT SERPENTINE AREA.

Extent.—Beginning under the andesite northwest of Town Talk, this area extends beyond the limits of the map to a point some distance northwest of the Yellow Diamond mine.

Description of rocks.—The serpentine in this area is only partly a pure rock and usually bears clear evidence of its derivation from pyroxenites and peridotites, in part probably also from gabbro. The residual masses of gabbro and diorite occurring in it have already been mentioned. In its northwestern point unaltered pyroxenites appear, while good peridotites are exposed where the Newtown road crosses its western contact.

While there is some of the pure light-green serpentine with glistening curved faces of the fragments, the prevailing rock is a black to dark-brown or dark-green dense rock, rather soft and with dull surface, in places showing, however, a peculiar satiny luster. Occasionally, as, for instance, in the rock from the old tunnel 2,300 feet south of the Wyoming mill (116 N. C.), the serpentine of the appearance just referred to is fairly pure and shows a grate structure by development of more sharply bi-refracting fibers crossing each other at varying angles. There are, further, some tremolite or actinolite, a little talc, and abundant irregularly distributed magnetite, and, lastly, clouded and corroded remains of a pyroxene mineral.

A specimen from the north side of Deer Creek, 2,500 feet west-southwest of the Providence mine (131 N. C.), is a black, apparently fine-grained rock with a satiny luster. The microscope shows it to be a very imperfect serpentine. There is a large quantity of clouded residual pyroxene, probably enstatite, traversed in all directions by radiating or crossing fibers of serpentine with gray colors of interference. The olivine is not so easily recognized, but is probably also present. Some secondary actinolite in radiating fibers traverses the pyroxene; aggregates of talc are also noted. The magnetite is abundant, anhedral or in sharp crystals, and arranged to form an incipient net structure, best seen in reflected light. Pyrite also occurs in this rock, in anhedral grains closely associated with magnetite.

A serpentinoid rock of similar appearance from near the contact north of Pleasant Flat shows remains of pyroxene and olivine; the serpentine traverses the original minerals in net-like veins composed of a very cryptocrystalline, clear mass. Talc and actinolite are present, as usual. It should be noted, however, that it is impossible to distinguish fine micaceous aggregates from talc, and if feldspar was present in the original rock white micas might be expected in the resulting serpentine.

Weathering.—This impure serpentine derived from pyroxenite and peridotite is very resistant to surface decomposition. It forms reddish-brown, rough outcrops, with practically no residual soil. West of Indian Flat a probably thermal alteration has produced a large mass of brown or white, cellular, chalcedonic rock. Moss agates, so called, consisting of translucent chalcedonite with black dendritic inclusions, have been obtained from this locality.

Relation to surrounding rocks.—The contact with the amphibolites on the east is distinct, though insufficient exposures do not permit a satisfactory establishment of the relation between the rocks. The contact on the west with the wedge-like projecting serpentine masses has already been referred to.

THE TOWN TALK SERPENTINE AREA.

This small area, 1,500 feet long and only a few hundred feet wide, is in character of rock similar to the larger mass just described. Residual pyroxene, and occasionally olivine, is contained in the serpentine, as well as secondary actinolite. One specimen with dense, dark-green, flinty appearance is a mixture of serpentine, chlorite, and actinolite. On account of unsatisfactory outcrop, nothing definite can be said about its relation to surrounding rocks; it lies as a dike-like mass between dark-green porphyrites on the west and black clay-slates on the east.

A similar small area with some gabbro at its southern end is found north of the Washington mine, southeast of the Town Talk area.

THE MARYLAND SERPENTINE AREA.

Extent.—Beginning as a narrow wedge in gabbro northeast of Newtown and flanked by smaller masses of peridotite and pyroxenite, this large serpentine area enters the special sheets west of the Fair-ground, and between the Maryland mine and Grass Valley sends out a long wedge-shaped mass southward toward the sulphuret works. Continuing southeast, the area runs out to points again; near the Brunswick mine two branches are separated by a mass of gabbro.

Description.—The rock is a normal serpentine of dull dark-green, dark-brown, or black color, sometimes containing veins of chrysotile; a light-green crushed serpentine, breaking in smooth, glistening fragments, is also found in places. Masses of diorite and gabbro are not abundant in it.

The rock in this area is much more normal than is the Indian Flat serpentine. In most of the specimens examined the serpentinization is complete, no remains of the original minerals being found. The structure is, as a rule, an imperfect grate structure, by the development of stronger bi-refracting fibers crossing one another at varying angles; between the fibers lies less strongly bi-refracting serpentine with undulous extinction. A little talc and actinolite occurs, but far less than in the Indian Flat area. There is abundant magnetite, sometimes arranged so as to form a net structure; a dark-brown, translucent chromite is also noted in some specimens. Finely disseminated pyrite was found in the serpentine 1,700 feet west of the Eureka shaft embedded in fresh serpentine and in chrysotile veins; it is closely associated with

the magnetite and sometimes included in it; in one place a cluster of small yellow needles was noted, possibly millerite or sulphide of nickel. The presence of some calcite in the rock renders it possible, however, that some of the pyrite may be due to the vein solutions.

North of the areas of the special sheets remains of pyroxene and olivine are more frequently found in the serpentine.

Weathering.—The rock weathers very much like that of the Indian Flat area, in rough, reddish-brown outcrops; the rocky serpentine hills are almost bare of any residual soil, and are characterized by a scrubby growth of digger-pine and thorny brush (Ceanothus).

Relation to surrounding rocks.—The contacts of the serpentine with the sedimentary rocks, as well as with diabase and porphyrite and with the gabbro and diorite, are fairly sharp; least so, probably, the gabbro contacts, but the decomposition of the rocks renders it difficult to obtain distinct evidence as to succession. The relations at the St. John shaft are shown in the diagram accompanying the description of that mine. Small bodies of serpentine are occasionally found in the diabase, as at the reservoir 1,000 feet southeast of the Maryland mine. Numerous dikes of diabase and porphyrite are found in this serpentine area, and will be discussed later.

THE CROWN POINT SERPENTINE AREAS.

At the Crown Point mine and northwest of it there occurs in the sedimentary rocks dike-like masses of serpentine in close connection with certain basic porphyrites, to be described later. The relation of the serpentine and porphyrite is very similar to that indicated in the St. John section, and the inference is scarcely to be avoided that the latter rock is subject to a serpentinization. Specimens from the New Eureka prospect shaft and from near the Crown Point show the presence of much actinolite and some chlorite in the serpentine. There is also some chromite. The rock from the latter locality (bridge by Crown Point mill, 116 G. V.) is not exactly like a normal serpentine, being dark-green, hard, and showing somewhat splintery fracture. Residual pyroxene was noted in this rock.

CHAPTER IV.

THE IGNEOUS ROCKS OF THE BED-ROCK SERIES—(CONT'D).

THE DIABASE AND PORPHYRITE GROUP.

DEFINITIONS AND GENERAL FEATURES.

Under diabase are here included hypidiomorphic granular rocks composed chiefly of a soda-lime feldspar with augite; hornblende may partly or even wholly replace the augite. The texture ranges from coarse to rather fine grained, the latter forming transitions to the porphyrite group. The typical structure distinguishing it from the gabbros is "diabasic granular" or "ophitic," characterized by long, lath-shaped feldspars, the interstices being filled by the augite. Through a more granular development of the feldspars frequent transitions to dioritic structure are effected. It was proposed to restrict the term "diabase" to those rocks carrying basic feldspars (labradorite to anorthite), but this has not proved feasible without creating too artificial distinctions.

Under diabase-porphyrite are included the finer-grained forms of diabase in which are contained phenocrysts, usually of feldspar, thus giving the rock a porphyritic habit.

Under augite-porphyrite and hornblende-porphyrite are here included the pre-Tertiary porphyritic rocks, consisting chiefly of soda-lime feldspar and augite, hornblende, or biotite. The structure is porphyritic by phenocrysts of any of these constituents. The groundmass is chiefly feldspathic, ranging from cryptocrystalline to microcrystalline; very common is a pilotaxitic structure forming a transition to the diabase-porphyrites. In these porphyrites the feldspar is, as a rule, somewhat less basic than in the diabases. No glass has been detected, but remains of it might well have been devitrified and thus escaped attention. The porphyrites are probably chiefly effusive rocks, but may also occur as intrusive bodies.

Rocks belonging to this group have a wide distribution in the areas covered by the special maps. They are in general dark-green, rather basic rocks of medium to fine granular or holocrystalline porphyritic development, augite prevailing among the ferromagnesian silicates, though hornblende also occurs. Collectively they would formerly have been referred to as "greenstones." They range in composition from normal diabases, with from 47 to 53 per cent SiO_2 and rich in lime, to quartz-porphyrites of a composition similar to that of many granodiorites; the latter division is in general segregated from the rest and separately indicated. From the normal diabases there are gradations into hornblende-diabases and into augite-plagioclase rocks with a more

eu-granitic structure. Again, the diabase may readily become porphyritic, the resulting rock being referred to as diabase-porphyrite. A more pronounced porphyritic structure with finer-grained holocrystalline groundmass gradually leads over into the porphyrites, referred to as augite-porphyrites or hornblende-porphyrites. Besides these main divisions there are others less prominently represented, such as fourchites (J. F. Williams), or porphyritic rocks consisting chiefly of pyroxene, and augite-syenite, the latter probably only a facies of the diabase. There are further great masses of old tuffs and contact breccias among this group.

In face of such a variety of rocks, gradually changing in composition and structure and still by necessity to be regarded as a geological unit, the limitations of petrographical classification become painfully apparent. It can not be regarded as proved that the different areas occupied by this series are of exactly the same age, but the probability appears great that the time of eruption of all these rocks falls within moderate limits. They are much later than the Calaveras formation, being partly contemporaneous with, partly slightly later than, the Mariposa beds. Granodiorite appears to be the only principal rock which is decidedly later than the diabase-porphyrite series.

The frequent porphyritic character, and especially the abundant presence of fragmental rocks, characterize the group, in contrast to the granodiorite and the diorite-gabbro group, as surface eruptions, while the transition in granular diabases, on the other hand, tends to connect it with the intrusive rocks. It is probable that the group represents what is left of the extensive volcanoes which at the close of the Jurassic period were built up along the foothills of the Sierra Nevada. The erosion having removed the upper part, the remaining cores are exposed. The progressive eruptions of new material as the volcanic masses piled up will to some extent explain the close juxtaposition of rocks of intrusive and effusive types. Professor Iddings's descriptions of the Electric Peak rocks offer many analogies to the phenomena here presented. It may not be amiss to call attention to the fact that the rocks most resembling the effusive types of modern andesites are found about Banner Hill, in the highest parts of the area, but no distinct law governing the distribution of the different structures can be formulated.

Finally, this group has been extensively subjected to metamorphism, developing uralite, epidote, chlorite, pyrite, and other minerals, and sometimes converting the rock into amphibolitic schists.

A majority of these porphyrites are, strictly speaking, the somewhat altered and perhaps partly devitrified equivalents of the modern andesites, and might be called "apo andesites," according to a recently suggested nomenclature.

This or a similar classification has not been adopted because it was believed that great confusion would result. The gap existing between the Tertiary andesites and the Mesozoic porphyrites is, in the Sierra Nevada, very wide and marked.

THE DIKES IN THE FEDERAL LOAN ARGILLITES.

General features.—Very many dikes are contained in the partly contact-metamorphosed rocks of this area, but most of them are of small extent and irregular form and can be traced only for short distances. It is rarely possible to trace them with great accuracy under the deep covering of residual soil; the impression of great extent gained by the abundant fragments is corrected by inspection of fresh exposures, as along the canyon of Deer Creek. Although occurring abundantly close up to the granodiorite, none have been found in that rock. They usually contain a considerable quantity of sulphides, as do the argillites in which they are contained, and also, as the argillites, secondary biotite.

Fourchite.—The fourchites, according to J. F. Williams,[1] are characterized as porphyritic rocks with phenocrysts of augite in a prevailingly augitic groundmass. Rocks of this character, really the porphyritic equivalent of pyroxenite, occur in this area at two places—as a small dike a few feet wide at the foot bridge 500 feet northwest of the Federal Loan mine (52 N. C.), and as a larger dike at the andesite dike north of Willow Valley Creek. The latter is adjoined southward by another dike of quartz-porphyritic character. The dark-green rocks carry augite crystals, colorless in thin section, green in specimen, several millimeters large, of stout prismatic habit, partly uralitized and showing peculiar twinning, sometimes with polysynthetic lamellæ, probably parallel to a dome or a pyramid. The groundmass is chiefly a fine aggregate of small prismatic or anhedral uralite grains with a little sericitized feldspar.

Diorite.—A dike-like mass of dioritic rock occurs on the divide between Scotts Flat and Willow Valley, at the road to the former place. It is a dark-green, medium-grained rock, consisting of roughly idiomorphic, brown, partly bleached hornblende, lath-shaped plagioclase and a little orthoclase, the latter cementing the plagioclase prisms; very abundant titanite and pyrrhotite, the latter possibly primary in part; much chlorite and epidote. Though a diorite, the rock is believed to to be closely related, geologically, to the diabase eruptions.

Porphyrite.—Dikes of this character are most frequent, and the rocks may be classed either as hornblende-porphyrites or quartz-hornblende-porphyrites. They are in general dense, dark-gray rocks, with a tinge of green or brown, with phenocrysts of hornblende, in some cases up to 2 cm., but usually 1 to 3 mm., in length. The feldspar phenocrysts are less conspicuous. Under the microscope the hornblende, while more or less uralitic, bears evidence of having been originally of dark-brown color; maximum extinction, 20°. The feldspar phenocrysts are well defined, but usually obscured by sericitic and epidotic aggregates. The holocrystalline groundmass is, in the quartzose porphyrites, of a fine-grained, allotriomorphic character, while in the quartz-free rocks it

[1] Arkansas Geol. Survey, 1890, Vol. II.

readily assumes a pilotaxitic structure by the microlitic development of the feldspars. The groundmass is prevailingly composed of feldspar, though in the quartz-free porphyrites there are also small prisms of uralitic hornblende. Many of the rocks contain finely disseminated, reddish-brown biotite in the groundmass and in the uralite crystals; this biotite is probably not primary, but has been developed by metamorphic processes. It can scarcely be due to contact metamorphism, for the granitic contact is for many of the occurrences several thousand feet distant. A similar development of brown mica will be shown in the metamorphosed diabases of the Nevada City area. Magnetite is abundant, as is pyrite, and especially pyrrhotite. In part these sulphides are doubtless secondary, but in other sections (32 N. C.), where intimately intergrown pyrite and magnetite fills many of the hornblende crystals, a primary origin suggests itself strongly. Chlorite, epidote, and sericite are abundant. On the whole, the rocks may be characterized as greatly altered, though no mechanical effects of dynamometamorphism are visible. Specimen 22 N. C., from near the edge of the Banner Hill area, 200 feet south of the Scotts Flat road, was analyzed. It is a dark-gray, fairly fresh rock, porphyritic by black hornblende crystals of prismatic habit, about 3 mm. long; the feldspar phenocrysts are small and not prominent. The groundmass is dense, grayish-brown, with splintery fracture. Under the microscope the hornblende is greenish-brown, and shows sharp idiomorphic outlines. The feldspars are filled by epidote and a sericitic mineral. The groundmass is a very fine grained, allotriomorphic, feldspar-quartz aggregate, with a great development of small chestnut-brown biotite foils.

The following analysis of this rock was made by Dr. H. N. Stokes:

	Per cent.
SiO_2	62.09
TiO_2	.32
P_2O_5	.39
SO_3	.10
Al_2O_3	16.69
Fe_2O_3	1.45
FeO	3.76
MnO	Trace.
BaO	.10
CaO	6.08
MgO	1.93
K_2O	1.84
Na_2O	3.36
H_2O below 110° C	.19
H_2O above 110° C	1.47
	99.77

The chemical composition of this rock approaches very closely that of some granodiorites. Making due allowance for the CaO contained in the hornblende, there is evidently more Ab than An, and, besides, not so little orthoclase.

THE BANNER HILL DIABASE AND PORPHYRITE AREA.

Extent.—As shown by the general map (Pl. I), this area is entirely surrounded by sedimentary rocks of the Calaveras formation. The part of it shown in the southeast corner of the Banner Hill sheet is of almost bewildering complexity. Were the exposures better it might be possible to further subdivide the area. It is, however, unquestionably a geological unit, and according to the best evidence available the rock types are closely connected by transitions. The occurrence of brown hornblende characterizes most of the rocks in this area.

Description of rocks.—As no general description can be given, it is necessary to single out principal types. No. 71 N. C. (Banner Hill bears N. 20° W., and is 4,700 feet distant) shows in a grayish-green groundmass white feldspar crystals up to 1 mm. long, and stout, prismatic, black hornblende up to 10 mm. in length. Under the microscope the idiomorphic brown hornblende, with extinctions about 20°, shows peculiarly rounded or corroded outlines; some stout, partly uralitized augite crystals are also present. The idiomorphic feldspars are largely converted to epidote and micaceous minerals. Grains of ilmenite or titaniferous iron ore partly converted to titanite are rather abundant. The groundmass is apparently holocrystalline and consists chiefly of small feldspar microlites mixed with small grains of uralite and chlorite. The rock is a typical hornblende-augite-porphyrite.

A specimen from the lower Quaker Hill road near the edge of the map (57 N. C.) is dark-gray in color with a brownish tinge, and indistinctly porphyritic by small feldspar and augite prisms. It contains abundant pyrrhotite. In thin section the colorless, prettily idiomorphic augites are partly uralitized, the feldspars being completely decomposed to epidote, micaceous aggregates, and cloudy masses, probably kaolinite. The groundmass is holocrystalline and consists of medium-sized feldspar microlites, with uralite grains, chlorite, and a little dirty-brown biotite; there is very little magnetite, but pyrrhotite is extremely abundant and apparently of secondary origin. In structure this rock stands between a diabase-porphyrite and an augite-porphyrite.

The rock from the extreme southeast corner of the Banner Hill area is a very decomposed, fine-grained, but otherwise normal diabase.

A specimen taken at a place where Banner Hill bears N. 36° W. and is 4,500 feet distant, is a dark-green, coarse, granular rock composed of large (up to 5 mm. in diameter) augite crystals and grains, light-green in color and surrounded by a rim of black hornblende. Between the augites lies finer-grained white feldspar. The microscope shows large grains and imperfect crystals, often-twinned, of clear, and colorless augite,

usually surrounded by a border richer in inclusions, chiefly small fragments of brown hornblende; this again is surrounded by an outer rim of clear brown hornblende, bearing every evidence of being a primary constituent. There are grains of magnetite or ilmenite in the hornblende, and also much leucoxene. Pyrite occurs occasionally, with chlorite or intergrown with magnetite. The plagioclase is related to labradorite and occurs in smaller, sharply lath-shaped crystals between the large augites; it is frequently included in the hornblende, more rarely in the augite. Between the laths lies brown hornblende, more rarely augite, occasionally also quartz. A little chlorite, epidote, and uralite occur in the rock. The structure of the rock is distinctly diabasic.

Still another rock, occurring on the Quaker Hill road near the eastern limit of the special sheet, is a medium-grained hornblende-diabase. Both the brown hornblende and the feldspars are partly idiomorphic, though sometimes the latter determines the outlines of the former. This rock is extremely rich in probably secondary pyrrhotite.

Composition.—No analyses of these rocks have been made. On the whole the composition is doubtless that of a diabase, though the porphyrites may be somewhat more acid. Quartz-porphyrites do not appear to occur here.

Weathering.—The rock weathers to a deep, reddish-brown soil of clayey character. The disintegration of the rock has, however, not attained any depth approaching that of the granodiorites.

Relation to other rocks.—On the northwest the area borders against the argillites of Banner Hill, and the contact is of a complicated character, a zone of contact-breccia half a mile wide separating the two formations. There are, in fact, no distinct contacts. The massive rocks gradually change to a porphyrite-breccia of generally small, brown or greenish, firmly welded, angular fragments of hornblende- and augite-porphyrites, with from cryptocrystalline to pilotaxitic groundmass; the feldspars are usually exceedingly altered and uralitic aggregates are common. Besides, the breccia contains more or less numerous sharp, gray to brownish fragments of siliceous argillite, often of the appearance of hornfels. This breccia is characterized by containing a very large amount of pyrrhotite and a little pyrite, while magnetite generally is absent. The pyrrhotite appears to be, largely at least, secondary and due to metamorphic processes.

Northwesterly over the summit of Banner Hill the sedimentary fragments increase, entirely predominating in the breccia, which then finally grades into unbroken argillite.

THE PITTSBURG DIABASE AND PORPHYRITE AREA.

Extent.—Beginning in the southwest corner of the Banner Hill tract and extending diagonally across the Nevada City tract, is a large area of rocks of dark-green color and diabasic or porphyritic character.

Separated by the Mariposa slates, a part of it extends north of the Fair-ground, and, appearing again on the north side of the andesite hill, continues as a narrow dike-like mass in the diorite of Pleasant Flat. The northwestern part of the main area is very much altered by metamorphic processes, which indeed to some extent have affected the whole mass and must be described separately.

Description of rocks.—Going up the northern branch of Wolf Creek, above the Washington mine, one meets with a great variety of coarser diabases and hornblende-diabases with finer-grained hornblende-porphyrites. In the southwest corner of the Banner Hill tract the hornblende-porphyrites prevail. A specimen of these, taken at Thomas ranch (89 N. C.), carries in a dark brownish-gray groundmass feldspar crystals 1 to 2 mm. long and larger black hornblende needles.

Under the microscope the porphyritic feldspars appear very much altered into micaceous aggregates. The brown idiomorphic hornblende is partly converted to green uralite with slightly smaller extinction. The groundmass is pilotaxitic, chiefly feldspathic, and shows flow structure around the phenocrysts. Small foils of brown mica, also a little chlorite and uralite, occur in the groundmass. Pyrite is rather plentiful, often intergrown with magnetite. Both magnetite and pyrite occur as grains in apparently fresh hornblende.

This rock was partly analyzed by Dr. H. N. Stokes, with the following result:

	Per cent.
SiO_2	59.17
CaO	6.66
K_2O	.88
Na_2O	3.4

These figures would indicate a rock with some quartz and a soda-lime feldspar approaching andesine.

Along the crest of the ridge and about Herring's reservoir the rocks are, as a rule, fine-grained to dense, and of dark-green to dark brownish-green color. The microscope shows them to be tuffs of augite- and hornblende-porphyrites containing small fragments of these rocks, larger anhedral grains of augite or feldspar, and some fragments of sedimentary rocks. About the Pittsburg mine and from there on northwestward, greatly altered, dark-green, medium-grained diabasic rocks prevail. The augite, nearly always more or less uralitized, is very prominent and occurs as anhedral or roughly idiomorphic grains which often show a tendency to become porphyritic. Where, besides this, the quantity of augite is great, transitions to the fourchites are formed; such are the rocks in Wood's Ravine, 1,200 feet below the Nevada City mill, and on Gold Flat, 300 feet west of East Orleans tunnel. The

feldspar, nearly always greatly decomposed, is in part lath-like, in part more anhedral, the widespread alteration making it difficult to obtain good determinations; on the whole the structure is only partly normal diabasic, and shows approximation to the dioritic.

Augite- and hornblende-porphyrites are also present in this area, as, for instance, north of the Fair-ground. Here the grayish-brown or greenish porphyrites contain small feldspar crystals and hornblende needles 3 mm. long in a groundmass composed chiefly of laths and short prisms of plagioclase, probably labradorite. Another rock in the same vicinity is an altered augite-porphyrite with phenocrysts of plagioclase and pyroxene in a groundmass of micropoikilitic structure characterized by microlites and grains of feldspar in larger quartz grains. This structure is very unusual.

The best exposures are found at the tunnel on the south side of Deer Creek, 900 feet below the Home mine, where the contact with the Mariposa slates happens to be laid bare in the bed of the creek. Fig. 1 illustrates the exposures and affords a key to the whole complex series.

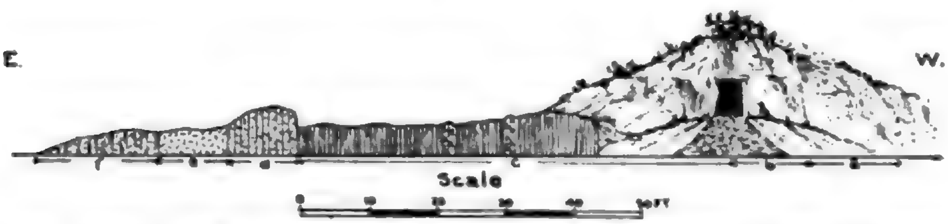


FIG. 1.—Section at tunnel 900 feet below Home mine, south side of Deer Creek. *a*, gabbro; *b*, serpentine; *c*, black mariposa clay-slate with tuffaceous sandstone; *d*, diabase-tuff; *e*, hornblende-porphyrite; *f*, augite-porphyrite, somewhat schistose.

The black Mariposa clay-slates begin at the tunnel and adjoin the serpentine on the west; they contain layers of tuffaceous sandstone and are again adjoined on the east by a dark-brown, fine-grained tuff. This tuff shows under the microscope colorless fresh augite fragments, in part altering to greenish uralite; between the augites lie fragments and aggregates of feldspar. The rock is greatly altered by development of secondary amphibole, biotite, etc.

Adjoining this tuff is a dike of normal greenish-gray hornblende-porphyrite with black hornblende phenocrysts and smaller white feldspars. East of this again is a greenish-brown, distinctly schistose augite-porphyrite greatly altered by secondary mineral growth.

On the whole, it appears probable that the hornblende-porphyrites are in part later dikes in the tuffs and diabases, though they undoubtedly in general belong to the same period of eruption.

Pyrite and pyrrhotite do not appear extensively in these rocks in the Nevada City tract.

THE PLEASANT FLAT URALITE-DIABASE DIKES.

Occurrence.—Across the diorite mass of Pleasant Flat extends a narrow area of fine-grained, dark-green rock, very evidently the continuation of the porphyrite area north of the Fair-ground, and similar rocks are found at many other places in the diorite area.

According to the evidence obtained at the narrow promontory separating Pleasant Flat from Stocking Flat, as well as at several other localities in the vicinity, this rock occurs as dikes in the diorite. On the hillsides the deep weathering makes the contacts uncertain. Very fine dikes, from 4 to 6 feet wide, of the same rock are exposed at the contact of diorite and serpentine at the head of Stocking Flat; they also occur in the serpentine.

Description of rocks.—All these rocks are chiefly fine-grained diabases, greatly altered by uralitization, which as a rule has left no augite, and by a more or less extensive recrystallization of the whole mass. A specimen from the contact dike, head of Stocking Flat (168 N. C.), consists of small grains and imperfect crystals of uralite in a feldspar mass which on the whole has a diabasic structure, although many of the feldspar laths are imperfect and transitions to dioritic structure appear. The character of the feldspars can not be well determined under the microscope, as very much secondary biotite and hornblende has developed in them. Ilmenite or titaniferous iron ore is present, but not any pyrite.

A partial analysis of this rock by Dr. Peter Fireman gave:

	Per cent.
SiO_2	51.29
CaO	6.57
K_2O	.34
Na_2O	4.39

Taking into consideration the fact that several per cent of the lime must belong to the uralite, it is apparent that the feldspar approaches an andesine.

One of these uralite-diabases contains a few small prisms of brownish, probably primary, hornblende, and in the same area are many smaller dikes of hornblende-porphyrite.

Weathering.—Like the Banner Hill diabase and porphyrite, the rocks in this area are deeply decomposed, and weather on the surface to the same dark-red clayey soil, from which occasional outcrops of more resistant rocks protrude. This fact makes it extremely difficult, except along the more deeply trenched creeks, to clear up the genetic relations of the different varieties and their relation to other formations. On the Red Hill, and especially on the slope of Deer Creek facing north,

the surface decomposition and oxidation reaches a depth of 20 feet or more.

Relation to other rocks.—Toward the argillites and schists of the Calaveras formation the diabase and porphyrite border with intrusive contact. In the southwestern part of the Banner Hill tract there are abundant contact breccias and dikes in the argillites. At the bluff just east of the Home mine (Deer Creek) the nearly massive uralite-diabase cuts across the Calaveras contact-metamorphosed quartzitic schists, showing the later and intrusive character of the former.

From the Home mine northward there are many dikes of diabase in the sedimentary schists. To some extent they are pressed and converted into secondary aggregates, but at many places, such as below the Wyoming mill and in Woods Ravine below the Nevada City mill, the relation of the two rocks is unmistakable.

The Mariposa clay-slates appear, as indicated by the relations stated above, to have been laid down practically contemporaneously with the eruption of the diabases and porphyrites; this is further confirmed by the tuffaceous exposures in the Merrimac mine and a short distance above the Washington mine, where the tuffs gradually change into clay-slates, a relation expressed on the map by the interlocking character of the contacts.

The relation of the series to the diorites and serpentines has already been referred to.

THE DIABASE DIKES IN THE MARYLAND SERPENTINE.

To the north of the railroad in the vicinity of the Maryland mine the serpentine contains a number of diabase dikes, usually following the same direction as the veins of the Idaho system, that is, west-northwest. The width of these dikes ranges up to 50 or 100 feet. The best preserved rock is found in the hanging wall of the Kentucky mine; it is hard, greenish-gray, medium-grained, and contains small grains of pyrite. Under the microscope the more or less regular lath-shaped feldspars with narrow striation and extinctions suggesting andesine are prominent, and their arrangement is that of the normal diabase structure; they contain abundant chlorite and white mica. There are remains of colorless augite, but the mineral is mostly converted into uralite, epidote, and chlorite, the latter filling the triangular interstices between the feldspars. The titaniferous iron ore is converted into milky titanite.

Other dikes on the Nevada City road opposite the Coe shaft and 500 feet northeast of it are similar, the latter containing remains of brown hornblende. The dike-like mass beginning north of the Maryland mine and extending up toward the Spring Hill is extremely affected by chloritic decomposition, but was once probably a diabase.

THE MARYLAND DIABASE AREA.

Extent.—Beginning on South Wolf Creek, this area extends up to the reservoir southeast of the Maryland mine in a rough crescent form.

Description of rocks.—The rocks are dark-green, medium- to fine-grained, normal diabases, characterized by the presence of dark-brown hornblende besides the augite.

A typical rock, unusually fresh, occurs on this road 425 feet west of the reservoir above the Maryland mine (121 G. V.). It is medium-grained and carries much pyrrhotite in small grains.

Under the microscope the feldspars appear in long lath-like form, in part also as irregular grains. The twin lamellæ are rather broad, but the symmetrical extinctions indicate that the prevailing feldspar is less basic than the labradorite. Between the laths lies, in places, a little of a fine-grained, interwoven aggregate of feldspar, sometimes showing an approximation to spherulitic structure. The augite is colorless and shows imperfect outlines, indicating that its recrystallization in part preceded that of the feldspar. Most of the augites are surrounded by a fringe of evidently primary brown hornblende. There is very little ilmenite or titanic iron ore, but a large amount of pyrrhotite and pyrite, the occurrence of which in the fresh augite and feldspar renders its primary character evident (fig. 2). Some of the interstices between the feldspars are filled by chlorite.

An analysis of this rock by Dr. H. N. Stokes gave:

	Per cent.
SiO_2	51.01
TiO_2	.98
P_2O_5	.17
CuS	Trace.
Al_2O_3	11.89
Cr_2O_3	.04
Fe_2O_3(*a*)	1.57
FeO(*a*)	6.08
FeS_2	1.73
MnO	Trace.
CaO	10.36
MgO	8.87
K_2O	.15
Na_2O	4.17
H_2O below 110° C	.24
H_2O above 110° C	2.09
	99.35

a Approximate only, because of presence of sulphides.

The rock appears to be a very typical diabase. Considering that several per cent of the CaO must belong to the augite, it is at once apparent that the average composition of the feldspars does not reach (Ab_1An_1), but is rather that of an andesine. Sulphide has in the analysis been calculated as FeS_2, only that compound being present in the sample; in the specimen from the same outcrop from which the thin sections were taken a large quantity of pyrrhotite was identified by Dr. Stokes.

Other rocks in the vicinity are similar, but usually contain more chlorite; in some the pyrrhotite is more or less completely replaced by black iron ores.

The diabasic rocks from the hanging wall of the Idaho-Maryland vein are grayish-green, extremely chloritic rocks, often containing much carbonates and sericite. In thin section the all-pervading chlorite generally veils the original character, but it is suspected that several varieties of rocks are present. The rock from the hanging wall, fifteenth level (145 G. V.), shows chiefly a mass of feldspars of imperfect lath-like form, between which lies much chlorite. The extinctions indicate a rather acid plagioclase. Other slides, from the sixteenth level near the incline, show a chloritic mass in which lie very long and narrow lath-like feldspars, the structure in fact approaching the pilotaxitic groundmass of some of the porphyrites. Still another specimen, from the mine dump, shows a distinct tuffaceous character. This is not so surprising, for the workings of the mine now extend under the area indicated on the surface as schistose porphyrite, which area in fact is largely composed of pressed porphyrite-tuff.

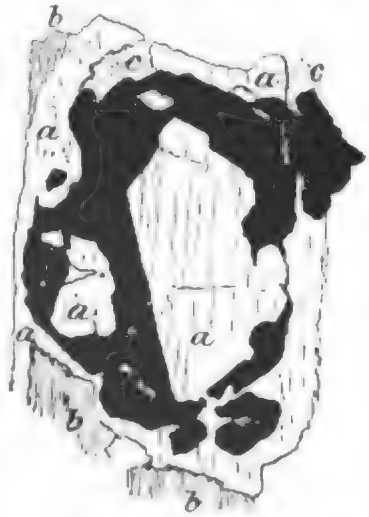


FIG. 2.—Primary pyrrhotite in augite; in diabase, 121 G. V. Magnified 60 diameters. Black—pyrrhotite; a, augite; b, uralite; c, chlorite.

A partial analysis of No. 145 G. V., by Dr. H. N. Stokes, gave:

	Per cent.
SiO_2	57.94
CaO	1.85
K_2O	.21
Na_2O	8.95

The large percentage of Na_2O and the small amount of CaO are very unexpected, but the rock is much altered and it is not safe to draw any conclusion as to its original composition.

The principal rock exposed in the shaft of the South Idaho is a very

typical uralite-diabase. Between large, long, and slender laths of feldspar, well filled with secondary epidote, lies fibrous, pale-green, uralitic hornblende. Narrow veins of a white mineral cross the specimen, evidently related to epidote, but showing exceptionally low colors of interference; the extinction is oblique to the well-developed cleavage. A partial analysis by Mr. George Steiger showed the mineral to contain:

	Per cent.
SiO_2	42.30
Al_2O_3 (with some Fe_2O_3)	30.10
CaO	17.30
MgO	Very little.
Ignition	4.70

The mineral must thus be regarded as an epidote exceptionally poor in iron.

The rock in the sharp railroad curve 2,100 feet south of the Maryland mine is very fine grained uralitic diabase, in which, however, the typical structure is less well developed. Remains of augite and brown hornblende were noted. The slide contains veins filled with white epidote and chlorite, together with a secondary mineral with strong double refraction, probably scapolite.

Relation to other rocks.—The irregular contact toward the gabbro on the west has already been noted, the diabase intruding as dikes in the former rock. On the northeast the contact toward the serpentine is distinct. On the east the diabase borders, with extremely indistinct contact, more in the nature of a transition, toward the schistose porphyrite-breccia.

THE AUGITE-SYENITE OF SOUTH WOLF CREEK.

Half a mile east of the Grass Valley railroad station is a small area of a grayish-green, medium-grained rock of diabasic appearance, usually containing scattered grains of pyrrhotite. The rock occurring 1,200 feet west of the lower sulphuret works (64 G. V.) consists, as seen in thin section, of lath-shaped plagioclase crystals much clouded and filled with micaceous products, and augite as short stout crystals or filling triangular interstices between the feldspar laths. Cementing all these constituents is a fresher and clearer feldspar without twin lamellæ, which evidently is orthoclase. Small amounts of uralite and chlorite are present, while most of the titanic iron ores are converted to leucoxene. A partial analysis of this rock by Dr. H. N. Stokes gave:

	Per cent.
SiO_2	51.47
CaO	7.72
K_2O	3.76
Na_2O	2.92

The presence of such a large quantity of K_2O in this rock is remarkable and allies it to the augite-syenites, or more correctly to the monzonites of Brögger. It is not, however, probable that it is a geologically independent body, for its affiliations are clearly with the Maryland diabase area, and it is probably only a facies of that rock. The relations of this area to the surrounding serpentine and Calaveras formation are obscured by the extensive weathering.

THE DIABASE AND PORPHYRITE DIKES IN THE CALAVERAS FORMATION OF GRASS VALLEY.

The medium-grained to aphanitic, dark-green dikes in the Calaveras formation nearest to the granodiorite are, as a rule, fine-grained diabases and diabase-porphyrites, uralitized in part. They frequently contain pyrrhotite intergrown with black iron ores; at least a part of this pyrrhotite is probably primary. The exposures are not satisfactory, the dikes occurring in the central part of the city.

From the Crown Point to north of the New Eureka there extends, in closest connection with the serpentine, a series of dike-like masses of varying structure. They are chiefly diabasic rocks consisting of augite surrounded by brown hornblende, feldspars without pronounced lath shape and often not striated, pyrrhotite, and black iron ores. But hornblende-augite-porphyrites with fine-grained, holocrystalline groundmass also occur. All of these rocks are intensely altered; the augite and hornblende is changed to uralite, bastite, serpentine, and chlorite; the serpentinization is sometimes very pronounced; the feldspars are altered to strongly bi-refracting aggregates, which in part are muscovite, in part probably a scapolite. The black iron ores are converted into leucoxene and chlorite, while sometimes secondary pyrrhotite is also found.

In the New Eureka shaft a series of very peculiar altered serpentinoid rocks were found, consisting of a fine felted mass of chlorite and serpentine containing large distinct foils of white and reddish-brown mica. It seems evident that the diabase and porphyrite are here undergoing a process of serpentinization, but in what degree the serpentine to the northwest has resulted from these rocks is not clear.

In the St. John shaft a very varied and interesting series of rocks have been exposed. The relations of the serpentine to this are indicated in fig. 21, p. 220. The rocks comprise hornblende-diabases, sometimes also with primary brown mica; granular rocks consisting of reddish-brown mica, feldspar, and abundant quartz; and, finally, grayish-green quartz-hornblende-porphyrites. The latter carry idiomorphic hornblende and feldspar in a holocrystalline groundmass made up of imperfectly lath-like plagioclase, between which lies unstriated feldspar and quartz. Nearly all of the rocks carry pyrrhotite in intergrowth with magnetite, and the former is in part quite surely primary. The minerals in the rocks are extremely altered to bastite, chlorite, micaceous

products, and probably also to scapolite, by the ordinary metamorphic processes. Thermal waters have in addition produced abundant calcite and pyrite.

It appears as if the final result of the metamorphic processes would have been a serpentinoid rock consisting of serpentine, chlorite, and actinolite, in which lie larger bastite crystals.

THE NORTH STAR DIABASE AND PORPHYRITE AREA.

Extent.—This area extends in roughly rectangular form from near the North Star up toward the northwestern andesite area. It is bounded

Fig. 3.—Intergrowth of primary pyrite and pyrrhotite with titanic iron ore; in diabase (34 G. V.). Magnified 112 diameters. *a*, augite, *b*, hornblende, *c*, plagioclase; *d*, titanic iron ore; *e*, pyrite; *f*, pyrrhotite.

by the Calaveras formation on the west and by the granodiorite on the east, north, and south.

Description of rocks.—In the southeastern portion of the area medium-grained diabases prevail, in part very fresh and unaltered rocks. Typical specimens were obtained 1,600 feet southeast of the North Star mine (32 G. V.), 3,000 feet north of the Omaha mine (34 G. V.), and 1,300 feet north of the same mine (108 G. V.).

The second of these (34 G. V.) is a medium-grained, dark-green, fresh rock in which the black pyroxene and light-green feldspars are plainly visible. Grains of pyrite and pyrrhotite are scattered through the mass. Under the microscope the rock is shown to be very fresh, almost the only secondary mineral being a little chlorite associated with the hornblende.

The plagioclase occurs partly as long, lath-like crystals with narrow striation, the extinction indicating an oligoclase or andesine, partly also as irregular grains indenting the laths, the effect being often a ragged or patched appearance. Many of the irregular feldspar grains do not show twin lamellæ. The augite forms colorless grains, rarely idiomorphic, but often notching the feldspar laths, the whole indicating a more or less simultaneous crystallization. The augite is surrounded by sharply defined, brownish-green hornblende, not always of the same orientation. This hornblende is evidently a later magmatic growth, and not a secondary mineral. There is probably also a little quartz between the feldspar grains. The black titanic iron ore, pyrite, and pyrrhotite are clearly of primary origin, and the earliest products of consolidation, being included in all of the other minerals (fig. 3). The three minerals occur in very intimate intergrowth as irregular grains, the sulphides being included in the oxide, and vice versa. The titanic iron ore is most abundant. The structure, while in general diabasic, is not very typically so, on account of the less perfect lath-like development of the feldspar.

This rock was analyzed by Dr. H. N. Stokes, with the following result:

	Per cent.
SiO_2	53.19
TiO_2	1.34
P_2O_5	.13
CuS?	
Al_2O_3	17.12
Cr_2O_3	None.
Fe_2O_3 (a)	4.35
FeO (a)	5.16
FeS_2 (b)	.94
MnO	Trace.
BaO	Trace.
CaO	9.39
MgO	3.98
K_2O	.28
Na_2O	2.79
H_2O below 110° C	.17
H_2O above 110° C	1.21
	100.05

a FeO and Fe_2O_3 only approximate, on account of presence of sulphides.
b Calculated as FeS_2, but much Fe_7O_8 also present.

The rock is a typical diabase in composition and very similar to the Maryland diabase. In all respects similar to this rock is the specimen 32 G. V., referred to above.

Other specimens, such as 108 G. V. and 114 G. V., at Central North Star, show a much more typical diabase structure. They are uralite-diabases, with a large amount of black iron ore.

The rocks in the vicinity of the North Star mine are in general finer-grained, dark-green, and frequently porphyritic by small feldspar and more rarely augite crystals. They may in general be characterized as uralitic diabase-porphyrites ranging down into uralite-porphyrite with pilotaxitic groundmass. These rocks are greatly decomposed, abundant chlorite, epidote, and micaceous product being formed, as well as leucoxene from the titanic iron ore. The feldspars are not recrystallized as in the typical dynamo-metamorphic areas, but alter into epidote, micaceous products, and perhaps also scapolite. Segregations of secondary products occur, chiefly characterized by abundant epidote. Such a segregation was found on the dump of the tunnel of the Star placer mine in Wolf Creek, a short distance above the Omaha mine, and consisted of a coarse mass of epidote, magnetite, and pyrite, with crusts of chabazite; it was assayed and found to contain 1 ounce of silver per ton, but no gold.

A hornblende-porphyrite of fresh appearance was noted on a dump 300 feet east of the Rocky Bar deep shaft. It probably occurs as a dike in the prevailing denser diabase-porphyrite, which is filled with epidote and pyrite.

The prevailing rock at the Peabody mine is a fine-grained diabase. In the northwestern part of the area dark-green porphyrites, with unusually large white feldspar crystals, appear.

On the whole, there is in this area no marked dynamo-metamorphism, but an extensive alteration, resulting chiefly in epidote, chlorite, and pyrite, and there is evidently no new feldspar formed. This alteration is distinct from the dynamo-metamorphism, but, on the other hand, it is also distinct from and surely not caused by the thermal waters forming the quartz veins. Epidote can evidently not be formed by this thermal process, and the alteration shows besides no dependence on the quartz veins, not growing more intense as these are approached.

Weathering.—The rock in this area is deeply decomposed and covered by a clayey, red residual soil. The only good exposures are afforded by the mining operations. This zone of extreme disintegration and decomposition is sometimes 30 to 40 feet deep.

Relation to other rocks.—The contact on the west with the Calaveras formation is not well exposed. Near the North Star mill a 12-foot-wide mass of siliceous and jaspery rock, reddish or yellow, and containing nests and cavities with chalcedonite, lies on or near the contact, but of normal contact metamorphism there is no clear indication.

THE OSBORNE HILL DIABASE, PORPHYRITE, AND BRECCIA AREA.

Extent.—This large area occupies a considerable portion of the southeastern part of the Grass Valley tract. Beginning on South Wolf Creek, southeast of the railroad station, it extends by the Empire and W. Y. O. D. mines and finally forms the great prominent ridge of Osborne Hill.

Description of rocks.—The rocks are in general fine-grained to aphanitic, dark-green, and the constituents can rarely be made out with the naked eye. While not generally affected by dynamo-metamorphism, the rocks are often deeply changed by chloritic and epidotic alteration. Both massive rocks and breccias occur.

At the northern end of the area, between the granodiorite and the Calaveras formation, the rock is a dark-green porphyrite-breccia with fragments of siliceous argillite; it is highly altered and has evidently also been subjected to pressure. Films of chlorite and secondary hornblende obscure the relations of the minerals. Scattered grains of magnetite and pyrite occur in intimate intergrowth.

Near the Empire and W. Y. O. D. the rock is very fine grained uralite-diabase, at the latter place very rich in pyrite. The dark-green, fine-grained rock from the dump of the Golden Treasure shaft consists, in thin section, of abundant pale-green uralite in grains or roughly outlined crystals, containing magnetite and pyrite intergrown. The feldspars constitute an entirely clouded mass, once evidently forming lath-like crystals.

Very fine grained diabases occur in the vicinity of Houston Hill. The structure in thin section, which with low magnifying power appears almost pilotaxitic, becomes with higher power very typical diabasic granular by long triclinic feldspar laths, between which lie triangular masses, also anhedral or roughly idiomorphic crystals of colorless augite, undergoing a direct transformation into chlorite. The titanic iron ores are transformed into leucoxene and pyrite, and pyrrhotite appears in connection with chlorite. Often there are large quantities of uralite and epidote and new-formed aggregates of quartz (and feldspar ?) containing amphibole needles.

A rock from near the granodiorite contact at Leeman's ranch, 4,000 feet east of the Omaha mine, is a dark-green, medium-grained rock of diabasic appearance and containing a large amount of grains of pyrite. Under the microscope its greatly altered character is evident. There is no augite, but much brownish-green hornblende in irregular grains and shreds. An original mass of lath-like feldspars is entirely obscured by opaque aggregates of doubtful character, probably in part kaolin. Allotriomorphic aggregates of secondary quartz, possibly also some new-formed feldspar, lie between the altered feldspars. Magnetite and pyrite, in part intimately intergrown, are scattered through the mass,

in the feldspar, the hornblende, and the secondary quartz aggregates; there is no calcite. The rock contains a trace of copper.

Porphyrites also occur abundantly in this area. Northeast of the Empire hoisting works, and 1,200 feet distant, a greenish-gray rock with small white feldspar crystals was noted. It contains scattered grains of pyrite; one grain of chalcopyrite was also determined. Under the microscope the structure appears brecciated; the fragments are of a porphyrite, the augite or hornblende being converted into chlorite. The groundmass is very unusually fine grained, and has a probably hypocrystalline, hyalopilitic structure, though the glass was not identified beyond doubt; it may, however, have become devitrified. In places the rock is amygdaloid, the cavities being filled with chlorite.

Specimens from a shaft on the Lincoln vein, due east of the Golden Treasure shaft, show a typical augite-porphyrite; the idiomorphic feldspars are clouded by kaolin and strongly double-refracting aggregates, possibly of scapolite; the idiomorphic augite is usually characterized by porphyritic twin lamellæ. The groundmass is holocrystalline and composed of small uralite and clouded feldspar grains. Much pyrrhotite is present, intergrown with magnetite.

The rocks from the southern end of Osborne Hill are generally grayish-green, highly altered porphyrites, with a strong development of epidote.

The summit and larger part of the eastern slope of Osborne Hill is composed of a breccia of differing coarseness, chiefly made up of fragments of porphyrite and diabase-porphyrite, together with less of a gray or brownish, flinty, sedimentary rock. The feldspar in the porphyrites is usually altered to epidote and other secondary minerals, while the augite is converted to chlorite.

Weathering.—Over practically the whole area rests residual soil of greater or less depth, red color, and clayey character, and the exposures are only rarely satisfactory.

Relation to other rocks.—The brecciated character of the rock mass near the Calaveras formation has already been mentioned. Along the granodiorite contact the exposures are not satisfactory at any place, but dike-like masses of granodiorite in diabase were noted at many places from Little Wolf Creek southward.

THE ORLEANS QUARTZ-PORPHYRITE DIKES.

Beginning near the Orleans mine and extending at least as far as the Daisy Hill mine are a series of dikes of quartzose porphyrite, occupying a place similar to that of the dikes from the eastern part of the Banner Hill tract or some of the rocks from the St. John mine. This dike system probably extends farther south, as similar rocks are found at the Lafayette tunnel and other places on the western slope of Osborne Hill, but the outcrops are so obscured by heavy soil that it is scarcely possible to trace the dikes farther. Besides, the quartz-porphyrite at the Lafayette tunnel is less quartzose than that farther

north, and appears to grade over into normal porphyrite. A typical rock from the New Ophir claim (140 G. V.) is of light grayish-green color and contains some epidote. The grayish phenocrysts of feldspar, as well as augite or hornblende, now converted into chlorite, lie in a dense, almost flinty groundmass.

The plagioclase phenocrysts appear, under the microscope, filled with epidote and micaceous products, while the augite or hornblende is converted into uralite, chlorite, and epidote. The groundmass consists either of short feldspar laths, between which lies a little quartz, as a cement, or of a micropoikilitic intergrowth of feldspar laths and grains with quartz.

The rock was analyzed by Dr. H. N. Stokes, with the following result:

	Per cent.
SiO_2	63.39
TiO_2	.44
P_2O_5	.14
Al_2O_3	16.58
Fe_2O_3	1.41
FeO	3.08
MnO	Trace.
BaO	.11
CaO	4.76
MgO	2.15
K_2O	2.79
Na_2O	3.47
H_2O below 110° C	.22
H_2O above 110° C	1.87
	100.41

The composition is almost identical with the quartz-porphyrite from the Banner Hill area, the analysis of which is given elsewhere.

The relation of the quartz-porphyrite to the surrounding diabase is not clear at the main dike, but the intrusive character is apparent in the case of a small dike of the same material outcropping in the bed of the creek a few hundred feet farther down.

THE AMPHIBOLITE GROUP.

DEFINITION.

Under the name "amphibolite" are here included massive or schistose rocks composed chiefly of hornblende, usually with smaller quantities of quartz, feldspar, epidote, and chlorite. These rocks are here in most cases products of dynamo-metamorphic action upon primary igneous rocks of the composition of diabases or porphyrites.

THE INDIAN FLAT AMPHIBOLITE AREA.

Extent.—This amphibolite area really forms the northern end of the Pittsburg diabase and porphyrite belt. As the process by which the amphibolites have been produced has in fact affected all of the rocks in the belt mentioned, it is necessary to discuss to some extent the alteration over the entire area. It is very evident that the extreme mechanical deformation causing schistosity is not necessary for the production of thoroughly metamorphic amphibolitic rocks. The rocks designated "amphibolites" are in general schistose, though rarely very prominently so, and are not separated by a sharp line from the less altered diabasic or porphyritic rocks.

Description of rocks.—The less schistose amphibolites and the uralitized diabases are not readily distinguished by the naked eye, the fine-grained structure and dark-green color being common to both.

The first stage in the metamorphism consists in the uralitization of the abundant augite (and rarer hornblende) in the primary rocks; at the same time the ends of the crystals feather out in ragged and divergent aggregates of light-green hornblende, and needles of the latter scatter through the feldspars. It is not necessary, however, that this process should be completed before the alteration proper begins. The latter consists in the forming of clear, allotriomorphic granular aggregates of generally unstriated feldspars, quartz, epidote, with abundant newly formed green, frequently idiomorphic, hornblende and dark brown biotite; this hornblende should not be designated "uralite;" the forms assumed are well indicated in a figure of the Conrad tunnel amphibolite in a paper on the Ophir mines.[1] Besides these minerals, magnetite, pyrite, and pyrrhotite are formed and contained, equivalent to the other components, in the secondary allotriomorphic mass. This new-formed mosaic encroaches gradually on the original minerals; the remaining feldspars appear as remnants clouded by muscovitic minerals and epidote. The eventual result is the conversion of the rock into an even-grained, clear, and fresh mosaic, an aggregate of the secondary minerals.

Muscovitic minerals are not, as a rule, formed in this process, nor is chlorite, though subsequent alteration may produce them in the amphibolites. Very characteristic for this area is a strong development of secondary biotite. That contact metamorphism has not caused this alteration is indicated by the fact that the black Mariposa clay-slates, easily susceptible to the influences of that process, are not notably altered, while the surrounding diabasic rocks have been considerably changed. Toward the end of the area northwest of Indian Flat, however, it is possible that contact metamorphism is in part responsible for the alteration.

In the tuffaceous rocks from near the Herring reservoir the metamorphic processes are already noticeable. Uralite largely replaces

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 258.

augite, and a reddish-brown mica develops abundantly in the uralite; in some crystals the tendency appears to be to convert the whole mass into biotite of similar orientation. Between the original feldspars, and also to some extent in them, the biotite is also developing, as well as abundant needles of new amphibole (104 N. C.). In other specimens (105 N. C.) from the same place new allotriomorphic feldspar aggregates appear, forming with biotite and hornblende a clear mosaic. Pyrite and pyrrhotite, as well as some black iron ores, are also among the new-formed minerals making up the mosaic, the sulphides being formed contemporaneously with the biotite.

From the Pittsburg mine down to Deer Creek the prevailing rocks are dark-green uralite-diabases; remaining kernels of augite often indicate the derivation of the light, bluish-green uralite; the edges of the uralite are extremely frayed and ragged, and needles of new-formed hornblende penetrate the feldspar. The original feldspars are clouded and filled with micaceous aggregates and epidote; between them and in them new, clear mosaic aggregates are forming of feldspar, hornblende, quartz, etc.

North of Deer Creek the alteration increases; the rock 1,100 feet northwest of the Indian Flat schoolhouse is typical (161 N. C.). It is a fine-grained, very slightly schistose amphibolite of dark-green color. In thin section the rock presents a blotched appearance, from the occurrence of larger white spots in the more even-grained prevailing mass. The latter is a clear allotriomorphic mass of biotite and green hornblende in irregular but sharply defined grains and foils, with grains of new-formed feldspar. The white spots are the remains of larger plagioclase crystals, now clouded and filled with minute hornblende needles. The process by which this mass is converted into the clear mosaic aggregate is very well shown, the latter corroding the older feldspars in all directions; sometimes the feldspar is cut by veins of the mosaic. In other rocks from this vicinity remains of augite are seen.

Toward the Oro Fino mine, beyond the area of the special sheet, the amphibolite becomes more schistose and more completely recrystallized.

From the clear, fresh character of the new mosaic and the clouded and altered remains of older feldspar the conclusion might be drawn that this alteration precedes the formation of the new mosaic, or, in other words, that the rock was already considerably altered before the dynamo-metamorphism took place. This conclusion is, however, of doubtful value, for the new-formed feldspar is probably albite and much more resistant to alteration than the old soda-lime feldspar. While deformations of minerals by pressure are met with in these rocks, they are not nearly so prominent as, for instance, in the adjoining aplite dike or in the Calaveras sandstones of Grass Valley. Quartz being most susceptible to crushing, rocks containing it show most plainly the purely mechanical effects of dynamo-metamorphism.

THE BRUNSWICK AREA OF SCHISTOSE PORPHYRITE-BRECCIA.

Extent.—Beginning southeast of the Maryland mine, bordering against diabase, this area extends southeasterly by the Gold Point and Brunswick mines, adjoined on the northeast by serpentine and on the southwest by the andesitic tuff, to beyond the limits of the special maps.

Description of rock.—The rock over the whole area is more or less intensely affected by dynamo-metamorphism and has become schistose. At the Lucky mine and at the Brunswick the schistosity is more strongly developed, producing amphibolitic and chloritic fissile rocks. Less altered rocks (97 G. V.) occur on the road along the Gold Point ridge, at an elevation of 2,700 feet. The rock is a greenish-gray, fine-grained breccia, very hard and compact and roughly schistose. Lighter grayish or brownish fragments of siliceous argillite appear to shade over into the darker green fragments of porphyrite. Under the microscope the porphyrites are shown to be chiefly augitic, with very fine grained, partly pilotaxitic groundmass. A large part of the augite has been converted into uralite. The cement of the breccia is a very confused mass of chlorite, epidote, white mica, and needles of hornblende. Grains of pyrrhotite also occur, mostly connected with chlorite.

Least altered is the augite-porphyrite-breccia from near the edge of the Grass Valley tract, 500 feet east-southeast of the small Maryland shaft on the ridge (120 G. V.). It is a dark-green, very hard, fine-grained rock of slightly fragmental aspect. A partial analysis of this pure breccia, by Dr. H. N. Stokes, gave:

	Per cent.
SiO_2	47.03
CaO	13.20
K_2O	1.90
Na_2O	2.84

The low percentage of silica and large amount of calcium in this rock are somewhat exceptional; the prevailing feldspar must be of quite basic character.

Weathering.—The surface of this area is deeply decomposed, the dark-red, clayey soil making the exposures, as a rule, very unsatisfactory. At the Gold Point mine, 136 feet from the surface, the porphyrite-schist is entirely disintegrated to a crumbling yellowish rock.

CHAPTER V.

THE SEDIMENTARY ROCKS OF THE BED-ROCK SERIES.

GENERAL FEATURES.

The sedimentary rocks, consisting of clay-slate (argillite), siliceous argillite, quartzitic sandstone, and chert, occupy relatively small areas in the tracts described. Only rarely can the stratification be recognized, and it is then about vertical, and approximately coincides with the schistosity. The latter is always nearly perpendicular, though a slight dip to the east may sometimes be recognized.

CALAVERAS FORMATION.

DEFINITION.

The Calaveras formation includes the sedimentary rocks of Paleozoic age occurring in the Gold Belt. It is believed on good grounds that most of this formation belongs to the Carboniferous, but it is possible that older rocks may also be present, the scarcity of fossils making identification difficult.

In the areas referred to this formation no fossils have been found, and the evidence of age is only circumstantial. The beds are altered, but not in general completely recrystallized, though, under the influence of dynamic and contact metamorphism, they grade into normal crystalline schists.

The areas in the Grass Valley tract are the continuation of the sedimentary formations about Auburn and Colfax, in which a few fossils distinctly indicating Lower Carboniferous age have been found. The best locality is at the old limestone quarry 2 miles west of Colfax, from which Mr. C. D. Walcott has identified the characteristic corals *Clisiophyllum gabbi* Meek and *Lithostrotion whitneyi* var. *sublævis* Meek. The areas in the Banner Hill tract are the continuation of the series extending up by North Bloomfield and the Delhi mine, in which masses of limestone with crinoid stems have been found along the South Yuba River, indicating at least a Paleozoic age.

These sedimentary rocks are more resistant to weathering than the granodiorite, and in the Banner Hill and Nevada City tracts form a ring of hills rising like an amphitheater around the broad depression occupied by the granodiorite.

THE FEDERAL LOAN AREA.

Rock description.—The Federal Loan area contains, well exposed in the deep canyon of Deer Creek, a very peculiar sedimentary rock, black to dark-brown in color, very hard and dense, with a fracture ranging from imperfectly conchoidal to splintery. Minute grains of sulphides are abundantly scattered through it. It only rarely, and then in decomposed outcrops, shows a trace of schistosity, but is in general entirely massive. It looks much like certain very dense products of contact metamorphism, usually called hornfels, but the extent of the area outside of the special map shows that its occurrence is not dependent on the proximity of the granitic rocks. On the contrary, it forms an important part of the Calaveras formation in the area of the Colfax sheet, beginning north of Colfax and extending, several miles wide and magnificently exposed in the canyons of the South and Middle Yuba, up to the northern limit of that sheet, where it is cut off by igneous rocks. Within this area it becomes schistose in streaks, and then appears as siliceous clay-slate; it also contains some smaller lenses of limestone with crinoid stems (South Yuba Canyon). This rock may for the present purpose be called *siliceous argillite*, the word argillite being used to designate a fine-grained, clayey, sedimentary rock, whether schistose or not, which has undergone some alteration. It presents some similarity to the cherts of certain sedimentary series, but it does not occur in distinct layers as the radiolarian chert (phthanite) of the Coast Ranges, nor is it, like certain other cherts, derived from limestone. A certain similarity to lydite (Kieselschiefer) is also noted, but it contains much less silica than either chert or lydite. It is probably to be regarded as having been originally deposited as a siliceous clay, partly by the agency of radiolarian organisms, of which there are, indeed, indistinct traces in the rock. The metamorphism which the rock has undergone can not, as stated above, be regarded as contact metamorphism, but is more likely part of the regional and evidently dynamic metamorphism which has affected all of the sedimentary rocks of the Calaveras formation.

In the excellent outcrops along Deer Creek above Federal Loan, the black siliceous rock is seen to contain indefinite streaks of lighter color, which have a general north-south direction; this may be a faint remaining trace of stratification.

A rock from the ditch opposite Federal Loan, and 1,300 feet from the contact (23 N. C.), corresponds well to the above description; pyrrhotite is contained in minute grains and veinlets.

Under the microscope it resolves into an extremely fine grained, allotriomorphic, holocrystalline aggregate of quartz and probably feldspar. Very intimately intermingled with this mosaic are small flakes of reddish-brown biotite, and there are abundant larger and smaller grains of pyrrhotite, in all probability of contemporaneous formation

with the biotite. A little carbonaceous organic matter is also present. The slide is dotted by a few small round and clear spots of a coarser quartz aggregate. It is not impossible that these may be radiolarian remains.

The unaltered wall-rock from the Federal Loan mine (35 N. C.) is of similar appearance, but contains a few grains of pyrite, besides pyrrhotite and minute seams of calcite, noticeable only upon treatment with hydrochloric acid.

Under the microscope it appears a little coarser than the rock just described, and presents remains of a clastic structure by larger rounded grains of quartz or feldspar. The main mass is the same intimate mixture of brown, in part idiomorphic biotite foils and allotriomorphic quartz-feldspar mass. The feldspar is not quite fresh, being in part filled with micaceous minerals. Most of the sulphides are undoubtedly contemporaneous with the formation of the mosaic.

This rock was analyzed by Dr. W. F. Hillebrand, with the following result:

Analysis of wall rock from Federal Loan mine.

	Per cent.
SiO_2	73.63
TiO_2	.52
Al_2O_3	10.54
Fe_2O_3 a FeO a	1.87
CaO	2.47
SrO	Trace.
BaO	.12
MgO	1.84
K_2O	1.89
Na_2O	1.81
Li_2O	Trace.
P_2O_5	.13
CO_2	.62
Fe_7O_8	3.16
Carbon of organic matter	.59
H_2O below 110° C.	.11
H_2O above 110° C.	1.07
	100.37

a Because of organic matter and soluble sulphide, the FeO could not be estimated; therefore all iron after deduction of that needed for Fe_7O_8 is counted as FeO.

The analysis shows that the rock is not a lydite or "Kieselschiefer," as it contains too little silica. On the whole, the composition is similar to that of many so-called "Hälleflinta," although in the latter rock the

original clastic structure is wholly lost. It is too acid, on the other hand, for an ordinary argillite.

Weathering.—On the summits of the ridges this rock weathers to a white, soft, clayey mass, such as is exposed along the road to Scotts Flat, a little east of the eastern boundary of the sheet. The weathering is not, however, deep, and the rock on the whole shows comparatively great resistance to this process. Red soil, washed down from the adjacent masses of andesite and porphyrite, usually covers the surface.

Contact metamorphism.—For a few hundred feet from the contact the siliceous argillites are altered to more crystalline rocks; the best exposures are found in Deer Creek below the Federal Loan. The contact is extremely sharp, and near it, as mentioned, a dike of fresh granodiorite occurs in the altered rock. For the first few feet from the contact the sedimentary rocks are converted into medium-grained, grayish, slightly schistose, gneissoid rocks; the grain is of varying coarseness, and the rock presents a spotted appearance from the irregular distribution of the biotite, occurring abundantly as small black foils. A thin section 2 feet from the contact shows a coarse mosaic structure of quartz and feldspar without twin striation, with a few roughly lath-like plagioclase crystals and much reddish-brown biotite in straight foils, in part altered to chlorite. Five feet from the contact the grain of the rock is already finer, and in thin section the mosaic structure of quartz and some not twinned feldspars becomes more pronounced. Abundant small biotite foils and a few cubes of pyrite are inclosed in the fresh quartz grains.

For a few hundred feet back from the contact the rocks show a gradually diminishing grain until the normal structure, previously described, is attained. The typical contact rocks of this type are of brownish or brownish-violet color, fine-grained, but not flinty or splintery, and the biotite foils in them may be observed with the magnifying glass.

In thin section these rocks consist of a fine-grained mosaic of quartz and unstriated feldspar, easily resolved by a No. 4 Hartnack objective. Larger foils of reddish-brown mica with irregularly rounded outlines lie between the grains. The biotite is partly converted into chlorite. In the clear mosaic grains are embedded a great number of small biotite foils, the larger hexagonal, the smaller with rounded outlines; magnetite, pyrite, and probably also pyrrhotite, are embedded mostly as small crystals in the fresh quartz and feldspar mass. The sulphides are without doubt formed contemporaneously with the other contact minerals.

THE BANNER HILL AREA.

The sedimentary rocks occupy the northwestern steep slope of Banner Hill. Less altered black argillites of imperfectly schistose character occur at the old Banner mine and in the small area south of the andesite, while along the contact near the North Banner mine and up the creek hornfels or contact-metamorphosed siliceous argillites prevail.

Occupying the broad belt across the summit of Banner Hill is a

brecciated zone consisting chiefly of a hard, compact, and well-cemented mass of angular, gray to brown fragments of the same rock that has been described as siliceous argillite from the Federal Loan area.

In thin section the latter rock appears with its characteristic, extremely fine allotriomorphic structure, but with less biotite than near the Federal Loan; other fragments are of igneous rocks, and are identical with the augite and hornblende porphyrites of the adjoining Banner Hill area. The amount of the igneous fragments gradually increases until near that area they prevail and only occasionally gray or brown fragments of the sedimentary rocks appear. The igneous fragments are generally well preserved and show unaltered brown hornblende and greenish augite.

Very characteristic of this breccia is a recrystallization effected between the fragments and also in the sedimentary rock pieces. Allotriomorphic mosaics, sometimes rather coarse, have been formed, and consist of quartz, possibly also some feldspar, with a pale-green, anhedral mineral which from its cleavage and extinctions must be a monoclinic pyroxene, perhaps malacolite, though the small size of the grains did not permit its positive identification; it is certainly not an epidote. More slender greenish needles in the same secondary aggregate are a very light green amphibole. With this mineral combination is associated abundant pyrrhotite, giving evidence of direct connection with it by being surrounded by rims of the same pyroxenic mineral. This pyrrhotite is thus not connected with or formed by the auriferous vein solutions.

A fine-grained quartzitic rock occurring at the head of Little Deer Creek consists of a wholly crystalline allotriomorphic quartz-feldspar mosaic and abundant small grains of monoclinic pyroxene. This peculiar metamorphism of the Banner Hill breccia is interesting, and its cause is not quite clear. It may be the result of contact-metamorphic action of the porphyrite. It can hardly be due to the granodiorite, and of dynamo-metamorphism there is no indication.

THE CANADA HILL AREA.

The ridge to the south of Canada Hill consists largely of argillite, evidently the continuation of the Banner Hill area, covered in part by the andesitic flows. Over the larger part the exposures are very poor, but it is clear that the rock is not much altered. The prevailing rock is a black argillite with much carbonaceous matter, weathering gray and white and breaking in shelly pieces without clear schistosity. It is much softer than the Federal Loan rock, and does not have the splintery fracture of the latter. Where the area narrows, near the edge of the Banner Hill tract, a vertical schistosity about parallel to the granodiorite contact begins to appear. The original bedding of the rock is not clearly indicated.

Along the contact with the granodiorite there is a gradually fading contact zone of hornfels a few hundred feet wide.

THE NEVADA CITY AREA.

Extent and general character.—As a narrow belt, from 400 to 1,500 feet wide, and closely following the granodiorite-contact, the Paleozoic rocks of the Calaveras formation cross the Nevada City tract in a general northwesterly direction.

The rocks are generally very distinctly schistose and consist of black argillites or clay-slates, siliceous argillites, and quartzitic and micaceous schists. In the southeastern part a zone of contact-metamorphic rocks, a few hundred feet wide, lies next to the contact, while from near the Providence mine northward the whole belt is composed of highly altered schists, but whether all of this should be credited to the effects of contact metamorphism is doubtful.

Description of rocks.—Black, more or less fissile argillites occupy the eastern part of the area. The exposures are very poor; diabase-porphyrites, some very rich in pyroxene, occur as detached masses in the slate, and smaller masses of slate are embedded in the igneous rock.

Good exposures are noted where the creek draining Gold Flat crosses the area. Just south of the Orleans vein in this creek is a cropping of hard, brownish, schistose hornfels, with alternating lighter and darker streaks, probably indicating stratification; the schistosity is parallel to these and to the contact; the dip is 85° N. Flat joints dipping east intersect the schist. At Orleans shaft there are some gneissoid contact metamorphics and black clay-slate with knotty surface (Knotenschiefer). The contact metamorphism extends only 500 or 600 feet. Nearer to the diabase, in the same creek, are exposed fissile, dull-black slates containing much carbonaceous matter and finely disseminated pyrite; in these there is no indication of contact metamorphism.

Near the road south of the sulphuret works there are outcrops of fissile, weathered, knotty slates of silvery-gray color.

At the Fortuna mine the contact metamorphism is not strongly indicated. There are black, sooty, slightly knotty clay-slates and harder siliceous slates of a brownish color, indicating a development of biotite.

Farther west the metamorphism becomes more intense, and unaltered slates are no more seen. In the vicinity of the Crosby shaft some highly altered contact schists, streaked brown and green, are exposed, while the dumps indicate that the sedimentary rocks contain many diabasic dikes.

Brownish, highly altered, micaceous schists appear near the contact at the Providence mine. The good outcrops in the bluff near the Home mine show a fine-grained schist streaked brown and green by alternating developments of hornblende and biotite. The bluff is cut by joints dipping east and west at moderate angles, and the dark-green diabasic rocks, not at all or very imperfectly schistose in places, cut squarely across the schistose sedimentary rocks.

On the opposite side of Deer Creek, below the Wyoming mill, occurs

a dark-brown, imperfectly fissile argillite with a somewhat knotty surface and showing under the microscope a very fine grained, allotriomorphic mass of quartz, feldspar, and biotite, with much carbonaceous matter. Somewhat schistose, dike-like masses of amphibolitic rock are contained in this argillite.

On the dump of the Wyoming upper shaft were noted dark-brown, fine-grained, crystalline slates with much pyrrhotite in fine dissemination, certain streaks being richer in that mineral than others.

In Wood's Ravine, below the Nevada City mill, good exposures are found of fine-grained schists, streaked greenish and brown, cut by diabasic veins and in places containing small, lenticular, and pressed quartz veins, possibly the result of an older period of quartz formation than that to which the productive veins belong.

From here on northward the rocks are principally fine-grained, brownish schists, streaked brown, green, and gray, and often with hornstone-like fracture; there are also some greenish amphibolitic schists, which appear to represent pressed rock of originally diabasic character. In thin section the prevailing rocks consist of fine-grained quartz-feldspar mosaic with sharply outlined grains and flakes of hornblende, epidote, and biotite, and often show a streaky appearance by the arrangement of the latter minerals. This rapid variation and the usually predominant biotite separate them from the slaty amphibolites on the west.

Relation to other rocks.—These sedimentary rocks are distinctly older than the granodiorite on the east and the diabasic rocks on the west, both acting as intrusives toward the Calaveras slates. Some of the diabasic dikes show relatively slight alteration, while others are converted into amphibolitic rocks. Whether this is due to a difference in age of the latter or to differing intensity of the dynamo-metamorphic action is not certain.

The schistosity is in general parallel to the granodiorite contact, but from this the conclusion must not be drawn that the pressure from the intrusive granodiorite has produced the schistosity. In details, such as in the exposures in the crosscut on level 3 in the Nevada City mine, it is shown that the granodiorite cuts across the schistosity, which evidently was as strongly present at the time of the intrusion as it is now. No doubt the granodiorite has exerted a strong pressure on the schist masses, but it has mainly a pushing and bending action on the already formed schists. Toward the Coan mine the schistosity makes a distinct angle with the contact line.

The question of how far the alteration of the slates is due to contact metamorphism is an obscure one. To judge from available evidence from other parts of the special maps, the contact-metamorphosing action has not extended beyond a distance of a few hundred or a thousand feet.

THE GRASS VALLEY AREA.

General description.—This belt of sedimentary rocks, 1,000 to 2,500 feet wide, extends across the northeastern part of Grass Valley. To the northwest it extends under the covering area of andesitic material, as indicated by the dumps at the various shafts along the Alta channel. To the southeast it also probably continues under the andesites, as indicated by the small areas northeast and east of the Electric mine. The outcrops are very unsatisfactory, and consist chiefly of a grayish, medium to coarse grained, quartzitic sandstone and a very carbonaceous clay-slate. The former is characterized by many grains of dark-gray quartz. Near the granodiorite harder, dark-brown, contact-metamorphic rocks appear.

Fresh rocks found in the New Eureka and Crown Point mines look very different. They are hard, black, quartzitic sandstones, composed chiefly of small, clear grains of quartz and similar black argillites with imperfect cleavage, breaking in irregular fragments with smooth, glistening surfaces. The argillites contain many larger clastic fragments, chiefly of quartz, and both rocks contain pyrrhotite in great abundance as grains and seams with quartz. A little crystalline limestone of dark color was found on the New Eureka dump.

Microscopic description.—Under the microscope these rocks present several interesting features. The whole series appears extremely affected by dynamo-metamorphic action, most intensely manifested in crushing and fracturing. The clay-slates are composed of very fine grained aggregates with abundant newly formed muscovite, sometimes biting into the quartz grains, and much carbonaceous substance. A few larger crushed clastic grains were noted. Extreme crushing has practically converted some rocks to a breccia, traversed by small white veins, described below. Others show a pressed structure parallel to the cleavage, and some clastic grains are elongated in the same direction. Grains of pyrrhotite are very abundant throughout.

Still more interesting are the quartzitic sandstones (72, 73 G. V.). The clastic grains are chiefly quartz, while some feldspar, in part with twin lamellæ, is also present. Curved lines of fracture and small veins, chiefly of calcite and quartz, traverse the slides. The cement is recrystallized into an irregularly intergrown aggregate of quartz and feldspar with shreds of biotite, muscovite, and chlorite. Pyrrhotite also enters into the composition of this new-formed mass, and considerable organic matter is present. A few crystals of bluish-gray tourmaline were noted in the cement. The clastic grains are extremely pressed, and crushed to lenticular masses, showing all gradations between undular extinction and complete crushing and recrystallization to a finer aggregate. Besides, the newly formed quartz-feldspar mass between the grains is vigorously corroding the clastic grains and converting them to a finer aggregate. There is here an excellent illustration

of the intimate connection of dynamical and chemical processes in the recrystallization of rocks.

A specimen from the New Eureka shaft, 200 feet down (343 Nevada County collection), of a similar black quartzitic sandstone occurring as a small mass in serpentine, shows in addition to the small quartzose veins a second set of fractures, crossing the former and filled with serpentine. The serpentine in places extends into the clastic feldspar and quartz grains, corroding them in such a way as to leave no doubt that a local serpentinization has been in progress.

The feldspathic pyrrhotite veins.—In the description of the Crown Point mine the occurrence of a very remarkable vein is mentioned, consisting of pyrrhotite and chalcopyrite with calcite and very little quartz. The sulphurets are said to contain some gold, while of free gold there is practically none. The pyrrhotite contains only a trace of nickel. This type is so radically different from the normal gold-quartz vein that it must be considered separately, and undoubtedly has been formed under differing conditions.

The specimens and slides of the black argillite from near this vein, and also from the New Eureka shaft, contain a number of small white veinlets, occasionally widening out to larger bunches of the same compact white material. Small grains and streaks of pyrrhotite and copper pyrites occur on all these seams, and in one instance a little zincblende is probably also present; beyond doubt, the vein near the Crown Point is only a larger representative of this type.

Under the microscope the veins are seen to consist of quartz, calcite, and a plagioclastic feldspar, generally clouded and sometimes showing polysynthetic twinning. A small fragment of the feldspar was determined by Mr. George Steiger, by a qualitative analysis, as soda-lime feldspar approaching labradorite, the fusibility also agreeing with this result. In one veinlet (343 Nevada County collection) the feldspar occurs as small clouded prisms, between which lies clear quartz. This is the only occurrence of feldspar on mineral veins thus far known from this vicinity.[1] In the normal gold-quartz veins they have not thus far been found. The largest vein in the Crown Point mine shows no feldspar, but abundant light-green radial aggregate of chlorite, alike in the calcite, the quartz, and the pyrrhotite. This is also unknown from the normal quartz veins in this district.

Contact-metamorphic rocks.—For a distance of about 200 feet from the granodiorite contact dark-brown, fine-grained, quartzose, hornfels-like rocks appear, showing but little schistosity. In thin section a few larger clastic grains of feldspar and quartz lie in an extremely fine aggregate of the same minerals containing, besides, flakes of reddish-brown biotite and grains of magnetite and pyrrhotite. Organic matter is also present. In the smaller area south of South Wolf Creek normal

---

[1] Mr. H. W. Turner has recognized albite forming with quartz in a shattered zone in an albite-porphyrite from the Shaw mine, Eldorado County. Am. Jour. Sci., 3d series, Vol. XLVII, pp. 470, 471.

sandstones appear in the eastern part, while the part adjoining the diabase is a fine-grained breccia of this same hornfels-like rock, sometimes with fragments of porphyrite, and on the whole very similar to the Banner Hill breccia. Some of the same characteristic quartz-augite mosaic occurs in it, the latter mineral being here identified beyond doubt. According to the best evidence available, the porphyrite is earlier than the granodiorite. It is possible that the porphyrite in forming this breccia—which must be considered as a contact breccia—has had a contact-metamorphic effect similar to that of the granodiorite, though probably less intense. In fact, there is some evidence pointing in the same direction from the Gold Flat diabase area (Nevada City sheet), for that rock often contains fragments of sedimentary rocks in which a similar development of secondary biotite has taken place.

Quartz-tourmaline rock.—In the porphyrite adjoining the granodiorite just west of the Scotia shaft are poorly exposed masses of a gray quartzitic rock with dark-gray spots and blotches. In thin section this rock consists of an allotriomorphic mosaic of quartz in which lie masses of greenish-gray tourmaline, sometimes with roughly radial structure starting from a center of darker tourmaline. The ends of the tourmaline crystals grow into the quartz grains. This rock is regarded as a contact-metamorphosed quartzite.

THE NORTH STAR AREA.

Adjoining the diabase there extends along the western margin of the Grass Valley tract an area of sedimentary rocks. The exposures, as a rule, are very obscure. The area appears to consist of large ledges of a grayish chert, separated by black, imperfectly fissile argillite, weathering gray and breaking in shelly fragments. The chert is in places almost pure hydrated silica, and contains little vugs with quartz crystals. It is very different from the siliceous argillite from Federal Loan.

Along the poorly exposed contacts with the granodiorite and diabase there is not much evidence of contact metamorphism. No special examination has been made as to the origin of the chert so abundant in this area, but it is suggested that it may be derived largely from limestone by a process of silicification, such as has often been noted from other places in the Gold Belt. This view is confirmed by the occurrence, on the top of the ridge northwest of North Star, of a bowl-shaped depression or pit several hundred feet in diameter, and which can not be explained except as a collapsed limestone cave. It is indicated on the map as "Devils Punch Bowl."

MARIPOSA FORMATION.

The Mariposa formation embraces the uppermost part of the Jurassic, and is composed chiefly of a series of clay-slates.

During the mapping of the area of the Smartsville sheet the existence

of the Jurassic Mariposa slates, which south of Colfax are such a prominent feature of the foothill geology, was not recognized, nor have any fossils been found during the detailed examination in the rocks referred to this division. The evidence along other lines is, however, so strong that there can be no reasonable doubt that they are present.

The main belt of the Mariposa slates ends a short distance north of Colfax, being cut off by igneous rocks. The slates near Colfax are identified by the occurrence of several characteristic types of ammonites.[1] Lithologically they are characterized by black clay-slates and an abundant development of porphyrite-tuffs. About 7 miles north of Colfax a small streak of black tuffaceous clay-slates begins, and, extending under the andesite table, appears again a short distance east of the Washington mine on the headwaters of Wolf Creek. Here the series is quite extensive and consists largely of tuffaceous fissile slates, apparently gradually going over into porphyritic breccias.

A short distance northward the slates are replaced by porphyrite-breccia, but appear again in characteristic form near the Merrimac mine, on the dump of which fresh, black, tuffaceous slates are exposed, containing, as seen under the microscope, fragments of different kinds of porphyrites and of the brownish, siliceous argillite, entirely similar to that of Federal Loan, in an argillitic, very dense cement with much organic matter. The fragments do not show any evidence of considerable pressure. The slates near the mine contained much pyrite in sharp cubes.

The black clay-slates can be traced northward as a very narrow band, exposed in places by tunnels and ditches, until the excellent exposures along Deer Creek, mentioned above in the description of the Pittsburg porphyrite area, are reached. A short distance north of Deer Creek the belt ends. On the hill north of Deer Creek some siliceous argillite is exposed, besides the normal black, very fissile, and comparatively little altered clay-slate. A narrow isolated area of black clay-slate near Indian Flat has also been referred to this formation. Beyond this point the Mariposa slates have not been found.

The relatively unaltered character, the associated and interstratified porphyritic tuffs, and the occurrence of fragments of the older Calaveras formation are the evidences indicating beyond reasonable doubt that these rocks are younger than the Paleozoic formations. Throughout the area a steep or vertical dip prevails, and the schistosity coincides, approximately at least, with the stratification.

[1] *Perisphinctes colfaxi* and *Olcostephanus lindgreni*. A. Hyatt, Trias and Jura in the Western States: Bull. Geol Soc. Am., Vol. V, 1893, p. 395.

CHAPTER VI.

METAMORPHIC PROCESSES.

REMARKS ON METAMORPHISM.

Giving to the word metamorphism a somewhat wider sense than that in which it is commonly used, it may be defined as any transformation in the mineralogical composition or structure of a rock, with or without addition or subtraction of substance. This transformation can be brought about by different agencies and with widely differing results. The term metasomatism, or metasomatic action, is usually employed to designate a change in the chemical as well as the mineralogical composition, involving addition or subtraction of substance.

Restricting the wider definition of metamorphism, it is convenient to exclude from it the superficial weathering and disintegration, produced chiefly above the ground-water level by the action of atmospheric waters carrying oxygen and carbon dioxide. By this process there is not only a mineralogical transformation but the rock as such is destroyed. The products of this process are, besides soluble salts, chiefly silica, ferric hydrate, carbonates, and kaolin. Processes like cementation, or ordinary hardening of soft sedimentary rocks without extensive mineralogical or structural change, are likewise excluded.

Large metamorphosed areas are often spoken of as affected by regional metamorphism, a general term not designating the cause of the action. A large part of the Sierra Nevada may thus be said to have been subjected to regional metamorphism. The main cause, however, undoubtedly being orogenic pressure, the rocks are referred to as altered by dynamo-metamorphism. Strictly speaking, this term refers only to the purely dynamic processes of crushing and shearing by compressive stress distributed evenly through the rock or relieved along certain planes. A stretching action produced by a tensile stress has also been recognized by several investigators, but no decided evidence of its existence can be said to have been found during the examination of the rocks in this district.

While examples of dynamo-metamorphism without extensive mineralogical alteration occur, chemical forces are nearly always involved and very generally play a most important part, incited by the increase in temperature accompanying the pressure at points far below the surface and aided by the moisture of the rocks. It is not at all probable, however, that the heat during the dynamo-metamorphic processes in the Sierra Nevada has exceeded a few hundred degrees centigrade, and of

fusion there is no indication at all. It is not necessary for the initiation of the recrystallizing action that the pressure should have been carried to a point at which the limits of cohesion were reached and schistose structure produced.

The process should perhaps more fittingly be designated *dynamo-chemical* metamorphism. It generally is characterized by a very moderate hydration and the formation of clear, fresh aggregates of mosaic structure. It usually produces a rock of finer texture than the original one. Igneous and sedimentary rocks are similarly affected, though the ultimate products usually differ. The chemical composition of the rock does not appear to be greatly altered by the process.

Dynamo chemical metamorphism, best illustrated in this district by the Indian Flat amphibolite area and by the Grass Valley Calaveras slates area, ordinarily produces the following minerals: feldspar (probably very largely albite), quartz, hornblende, biotite, muscovite, chlorite (?), epidote, titanite, magnetite, pyrite, and pyrrhotite. The original feldspars are converted into albite, epidote, hornblende, quartz, and muscovite. The pyroxene alters to uralite and recrystallized hornblende, biotite, and epidote. The larger grains of clastic or porphyritic character are not only crushed but also resolved to secondary aggregates by a corrosively acting process of substitution, the new-formed minerals projecting into the primary grains.

Another and extremely prevalent form of metamorphism is apparent in certain rocks, such as the North Star and Osborne Hill diabase areas, which have certainly not been subjected to notable dynamic action. This process, characterized by the formation of confused mineral aggregates, not so much by clear secondary mosaics, and by a moderately extensive hydration, might provisionally be designated *common hydro-metamorphism.*[1] The process may evidently be begun and accomplished at a comparatively low temperature and depth under the influence of the moisture permeating the rocks below the groundwater level; the results imply that these were waters not oxidizing and which contained no great amount of carbon dioxide. As the depth increases, the character of the metamorphism will naturally change by reason of increasing temperature and static pressure.

The minerals formed are chlorite, serpentine, hornblende, epidote,[2] muscovite, probably also scapolite; further, magnetite, pyrite, and pyrrhotite; also zeolites. Secondary feldspars are apparently not formed in this process. The original feldspar alters to epidote, muscovite, and scapolite; the augite to hornblende, epidote, chlorite, and pyrite; ilmenite to titanite.

---

[1] About equivalent to Roth's "complicirte Verwitterung."

[2] Epidote contains mainly ferric iron, and it is hardly possible that it can have been formed under strongly reducing influences. It is, however, not necessary to suppose that it must have been formed under oxidizing influences, for rocks ordinarily contain a considerable quantity of ferric oxide. Pyrite has often been observed embedded in epidote. It does not seem probable that it can be formed by surface weathering under ordinary temperature and pressure. Compare G. F. Becker, Mon. U. S. Geol. Survey, Vol. III, p. 211.

One of the principal differences between this process and dynamo-chemical metamorphism is the absence of the secondary feldspar and the mosaic structure. It is clear from the above that, as the mineral series of the two processes overlap, there must frequently be great difficulty experienced in distinguishing them, and the processes may in fact gradually merge into each other. Many of the products of the hydro-metamorphism have formerly been regarded as caused by surface decomposition or weathering.

Another form of hydro-chemical alteration in which hydration plays the most important part is serpentinization, by which certain basic igneous rocks rich in magnesia may, over large areas and to great depth, be transformed into serpentine. Being an essentially deep-seated process, serpentinization should certainly not be referred to weathering.

Still another form of chemical alteration is that effected by thermal ascending waters, and which may conveniently be designated *hydro-thermal metamorphism.* The results of this may vary considerably according to the composition of the waters. If gaseous compounds of sulphur associated with aqueous vapor are the chief agents, it should be referred to as *solfataric metamorphism.* Under certain conditions the hydro-thermal metamorphism may be almost indistinguishable from the ordinary hydro chemical process, which indeed is to be expected.

In the case of the gold quartz veins here described, the waters were rich in carbon dioxide and sulphureted hydrogen, and the characteristic results of the intense metasomatic action are carbonates, muscovites, and pyrites.

Finally, by another transformation certain rocks may recrystallize when in close proximity to hot, intrusive, igneous magmas, principally those in a state of aqueous fusion. This is *contact metamorphism*, and its products are generally characterized by the same allotriomorphic, granular, fresh mosaic aggregate which characterizes the dynamo-chemical processes. The minerals formed are feldspar (chiefly albite), quartz, biotite, hornblende, pyroxene, andalusite, wollastonite, magnetite, pyrrhotite, and others. While the dynamo-chemical process tends to produce finer-grained aggregates than the original rock, contact metamorphism usually makes the texture coarser; this is illustrated by the contact near the Federal Loan mine. Nearly all sedimentary rocks and tuffs, as well as igneous rocks with a fine-grained groundmass, are subject to this alteration close to the contact, while coarser-grained igneous rocks appear to be but little affected; this is shown by the occurrence of fresh diabase close up to the granodiorite contacts.

The processes here enumerated are doubtless the most important ones, and each is in its way distinct and characteristic. Still, many places occur where it may be doubtful to which of these causes the effects observed are due, and especially difficult is the task when, as so often is the case, several kinds of metamorphism have successively

affected the rocks. Among these doubtful cases must be counted the metamorphism of the Banner Hill breccias, with their abundant pyrrhotite and new-formed aggregates of quartz and a mineral strongly resembling pyroxene.

ALTERATION OF FELDSPAR IN THE ROCKS BY HYDRO-CHEMICAL PROCESSES.

The orthoclase is, as a rule, far more resistant than the plagioclase. When it is altered the product is generally a white sericitic muscovite. Alteration to calcite has not been observed except in the vicinity of the veins.

The secondary products in the soda-lime feldspars may be of different kinds, and, on the whole, those feldspars are very readily altered. Hornblende and epidote frequently develop in them; also, to some extent, biotite. The basic feldspars of the gabbros often break up into fine-grained saussuritic aggregates of zoisite and albite, but this appears to belong in the realm of the dynamo-chemical processes. By far more common, however, is an alteration to products which very much resemble sericite, and the presence of this or a closely allied mineral can, indeed, in many cases be proved, even when the orthoclase in the same slide is not attacked. This is certainly curious, but, as is well known, Lemberg has shown by his analyses of decomposed plagioclases that, as a matter of fact, the final product is often rich in potassium. In many other cases there is, however, considerable doubt whether the new-formed mineral really is sericite or not. Being in very small particles, it is difficult to determine. The refraction is low and the double refraction strong, though not so strong as would be expected in muscovite, and it is suggested that the resulting mineral might possibly be scapolite, a mineral known to occur as a product of alteration of feldspars. An extensive kaolinization of the feldspars has not been recognized, and probably does not occur below the zone of surface weathering.

The only extensive occurrence of a kaolin-like mineral is that in the rhyolitic tuffs mentioned below.

OCCURRENCE AND FORMATION OF IRON SULPHIDES IN THE ROCKS.

General features.—Too little attention has been paid to the occurrence and genesis of pyrite and pyrrhotite, so common in the rocks of many districts. For the study of mineral deposits this subject has the deepest interest, and it may therefore be of some value to summarize the results attained in regard to this during this investigation.

Pyrite and pyrrhotite can be formed in many different ways, in fact by any of the processes above enumerated, except by weathering under ordinary atmospheric influences.[1] And still the pyrite in the rocks,

[1] It is recognized, of course, that the pyrite may be formed at the surface in the presence of strongly reducing influences.

when mentioned at all in descriptions, is often referred to as a product of weathering.[1]

Products of magmatic consolidation.—Pyrite and pyrrhotite may both be constituents of magmatic consolidation. Cogent proof of this is, of course, difficult to bring, and the fact is hardly yet quite universally recognized. The case recently described by Professor Vogt from Norway and the figures given here (figs. 2 and 3) from Grass Valley diabases leave, however, no room for doubt of primary origin. Besides the excellent occurrences in the Maryland and the North Star diabase area, these minerals have been so frequently found in other rocks, chiefly diabasic or porphyritic, under circumstances which strongly suggest, though not positively prove, primary origin, that the proposition may be confidently advanced that there are, as a rule, accessory primary constituents of the rock. As distinct traces of copper have also been found in one of the above-mentioned fresh rocks, it may be regarded as probable that chalcopyrite also occurs as a primary constituent.

Products of contact metamorphism.—Pyrrhotite has been recognized as an integral part of the allotriomorphic aggregates produced by contact metamorphism (Federal Loan area).

Products of dynamo-chemical metamorphism.—In the metamorphic rocks produced from igneous and sedimentary material pyrite and pyrrhotite have been observed as unquestionable constituents of the newly formed aggregates (Indian Flat amphibolite and Grass Valley quartzitic sandstone). Intergrowths of magnetite and pyrite are frequent. In certain amphibolitic schists in various parts of the Sierra Nevada large quantities of pyrite and chalcopyrite have been concentrated by these dynamo-chemical processes, forming the exact equivalents of the frequently described "fahlbands" from other parts of the world. It would seem suitable to reserve the designation fahlband for sulphides formed in schists by dynamo-chemical processes, thus not including in it schists altered by subsequent hydro-thermal action. These fahlbands sometimes appear to contain some silver and a little gold.

Products of common hydro-metamorphism.—Both pyrite and pyrrhotite have been developed abundantly in rocks subjected to hydro-metamorphism, and a little chalcopyrite has also been noted frequently. Developed in this way, the association with chlorite, as well as with epidote, appears characteristic. While the pyrite may occur as sharp crystals, it is more common to find it in anhedral grains often surrounded by chlorite rims. Pyrite and pyrrhotite often occur in intimate intergrowth with magnetite, and also filling seams and forming smaller segregated masses; pyrite and epidote are often found intergrown in this last-named manner.

Products of hydro-thermal processes.—Extremely abundant is pyrite in the metasomatic rocks accompanying the veins and formed under the

[1] G. H. Williams, The greenstone schist areas of the Menominee and Marquette regions of Michigan: Bull. U. S. Geol. Survey No. 62, p. 214.

influence of vein solutions. Pyrrhotite never occurs, while arsenical pyrites may be formed. Magnetite apparently can not be formed under the conditions prevailing in this process. Idiomorphic form, as sharply defined cubes, is most common. A frequently available criterion for the identification of the pyrite of this process is the narrow rims of calcite or quartz surrounding the crystals. Large cubes often occur developed porphyritically in rocks which have not otherwise been subjected to very intense hydro-thermal processes, and do not disturb the groundmass or crystals in which they are embedded. The process must be regarded as entirely one of substitution, or dissolving of the original substance and depositing in its stead the pyrite. The pyrite developed in this way is generally confined to the vicinity of the vein. Large areas are not in this district affected by hydro-thermal processes.

The cause of formation is in this case undoubtedly the action of the sulphureted hydrogen or alkaline sulphides in the water on the silicates and oxides of iron in the rock.

In many cases, especially where several alterations have been superimposed, it is of course extremely difficult to designate the exact mode of origin of the pyrite and pyrrhotite, but in typical cases these five modes of formation may be clearly distinguished.

In the last case there has clearly been an addition of sulphur to the rock; in dynamo-chemical, contact metamorphic, and ordinary hydrochemical processes it is not clear that any such addition has taken place. It is, perhaps, rather to be regarded as probable that the sulphides have resulted from a concentration and recrystallization of the sulphur and the iron primarily contained both in sedimentary and igneous rocks. On this point it is, however, not easy to speak definitely. By preference pyrrhotite seems to form in the presence of very strong reducing influences.

WEATHERING.

Under the above name are included changes in cohesion and composition wrought in the rocks near the surface, chiefly by the decomposing and oxidizing action of the percolating surface waters, partly also by the change of temperature. Most intense at the surface, the action gradually decreases downward, and, in most cases, practically ceases when the level of the ground water is attained, which suggests that it is largely due to the carbon dioxide and oxygen contained in the surface waters. The processes result in two zones, more or less imperfectly separated: First, the deeper and more extensive part in which incipient decomposition and hydration produce a disintegration; the rock becomes soft and crumbling, but the chemical composition is not greatly altered.[1] Second, a surface zone of extreme decomposition and oxidation, resulting in the formation of a residuary soil.

[1] This fact has been brought out recently by Prof. G. P. Merrill in his interesting studies on the decomposition of rocks: Bull. Geol. Soc. Am., Vol. VI, 1895, p. 321; Vol. VII, 1896, p. 349.

In the districts here described nearly all of the rocks are more or less deeply affected by those processes which may together be described by the not very apt expression "weathering." Deep-red residuary soil covers large areas, and the disintegration is sometimes found to extend to a depth of 200 feet. The granodiorite, the diabase, and the porphyrite, in some places also the andesite, are deeply affected, while the serpentine, for instance, is far more resistant to the weathering influences. The formation of such minerals as epidote and chlorite is here not considered as being due to the weathering, but to deep-seated processes. More detailed notes are found in the description of the different areas.

CHAPTER VII.

THE SUPERJACENT FORMATIONS.

While it is not intended to treat the Neocene deposits in detail in this paper, their general character may be briefly indicated.

AURIFEROUS GRAVELS.

The auriferous gravels proper, resting directly on the surface of the bed-rock series along the depressions of the Neocene rivers and creeks, consist, in the larger channels, of well-rounded pebbles of quartz and harder rocks of the bed-rock series, between which lies more or less sandy material. Although the gravel is largely quartzose, pebbles of other material are also plentiful. The size of the pebbles ranges from a fraction of an inch upward to cobblestones 6 or 8 inches in diameter, but the average size does not by far reach these dimensions. On the bed rock larger, partly rounded fragments occur occasionally. In the channels with granitic bed rock well-rounded bowlders several feet large are sometimes found in the bottom. In many of the tributary channels, such as the Harmony and the channel at the northwest end of Cement Hill, the gravel on the bed rock is partly angular and imperfectly washed. In the Harmony channel bodies and streaks of bluish clay alternate with streaks of gravel near the bed rock (fig. 6, p. 100). In the upper part of the gravel the pebbles are generally extremely well rounded and polished, and black, siliceous rocks make up a large portion of them. The deepest gravel has generally a dark-gray or bluish color, and contains much pyrite or marcasite, sometimes auriferous; streaks of reddish gravel also occur in the deeper parts of the mass. Nearer the surface the gravel is generally of reddish color. Fluviatile stratification is of extremely common occurrence. Very little gravel occurs in the Banner Hill area, though the lower parts of now largely eroded Neocene streams doubtless contained much of it. Very little gravel is found in the Grass Valley area also, and in the southern part of the Nevada City area. The largest accumulations are found north of Nevada City, in the deepest parts of the ancient stream system, where they reach a maximum thickness of 175 feet at the Manzanita hydraulic cut (fig. 4, p. 98). The banks of Cement Hill show 60 feet of well-washed gravel, with excellent fluviatile structure. Fig. 5 (p. 99) shows a nonconformity observed in the bluff.

RHYOLITIC TUFFS.

Above the auriferous gravels lie, in the deeper parts of the depressions, a series of light-colored or white clayey or sandy rocks, more or less perfectly consolidated, and commonly described as pipeclay and sand. These are largely rhyolitic tuffs, more or less pure. Certain of the beds consist nearly exclusively of minute fragments of glass, while others are so admixed with mainly granitic detritus as to nearly mask their tuffaceous character. The fragments, both of glass and of granitic minerals, are generally very sharp and angular. Besides, bodies of gravel are also included in the tuffaceous series, and, on the whole, it is impossible to draw a distinct line between the auriferous gravels and the rhyolitic tuffs. On the southern face of Cement Hill the line between the two formations is fairly sharp, separating 60 feet of gravel from over 200 feet of rhyolitic tuff. A little rhyolitic material is found in the sands of the main channels down to a distance of 40 feet, or even less, from the bed rock. The occurrence of the rhyolitic tuff is practically confined to the northern part of the Banner Hill and Nevada City tracts.

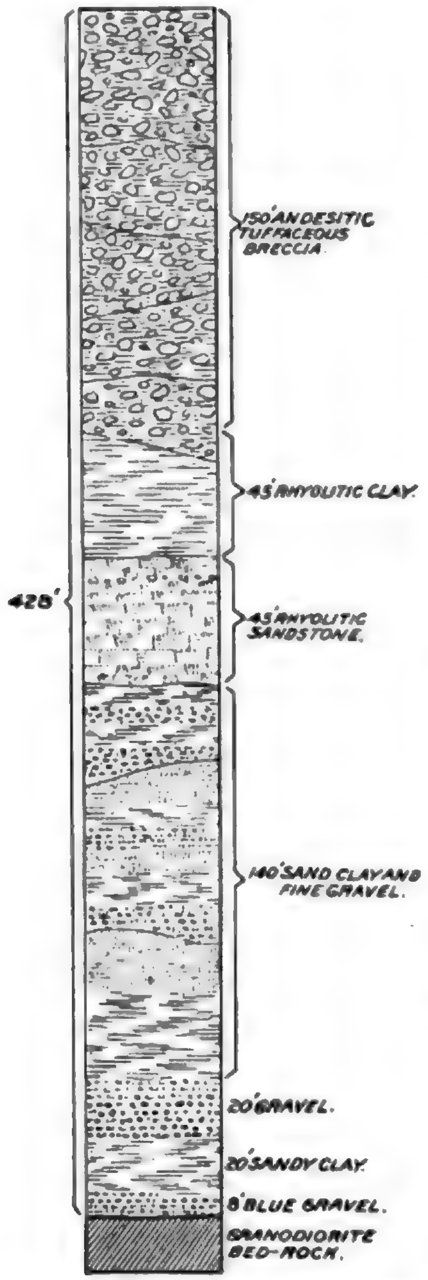


FIG. 4.—Section of superjacent formations at Manzanita mine, Nevada City.

The composition of several tuffs and sandstones is shown by the table on the next page; the partial analyses were made by Dr. H. N. Stokes.

It is apparent that the purest tuff has very nearly the composition of a rhyolite. Grains and flakes of a brownish translucent mineral, with faint double refraction, are abundantly developed, especially in the rocks poor in alkalis. This is undoubtedly the same kaolin mineral recognized by Mr. H. W. Turner in his Ione sandstone.[1]

[1] Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894 p. 464.

Table of partial analyses of clays, sandstones, and rhyolitic tuffs.

	2 N. C.	5 N. C.	7 N. C.	8 N. C.	10 N. C.	14 N. C.
SiO_2	69.54	67.46	67.94	69.06	75.65	62.70
Al_2O_3 Fe_2O_3	21.14	18.60	21.69	15.97	17.33	16.97
CaO	.30	1.18	.45	1.03	.29	.13
K_2O	1.26	1.76	1.64	5.00	.42	.32
Na_2O	.25	3.41	.20	1.38	.20	.13
	92.49	92.41	91.92	92.44	93.81	80.25

2 N. C.: Odin mine, 2 feet above bed rock. Sandy clay containing no rhyolite fragments.
5 N. C.: 800 feet south of Sugarloaf reservoir. Yellowish sandstone with rhyolite fragments; 100 feet above bed rock.
7 N. C.: West Harmony drift mine, 4 feet above bed rock. Sandy clay; no rhyolite fragments.
8 N. C.: 850 feet west of West Harmony incline. Pure rhyolite tuff.
10 N. C.: Manzanita pit, 10 feet above bed rock. White sandstone; a few rhyolite fragments.
14 N. C.: Hydraulic pit, west of Odin mine. Crumbling white sandstone; a few rhyolite fragments.

At the Cement Hill diggings, in the northwest corner of the Nevada City area, sandstones and gravel occur cemented by an almost pure, yellowish opal.

ANDESITIC TUFFS.

It has already been mentioned that the high, gently sloping ridges of these districts are covered by andesitic flows, and their general character as tuffs and tuffaceous breccias has also been described. As a

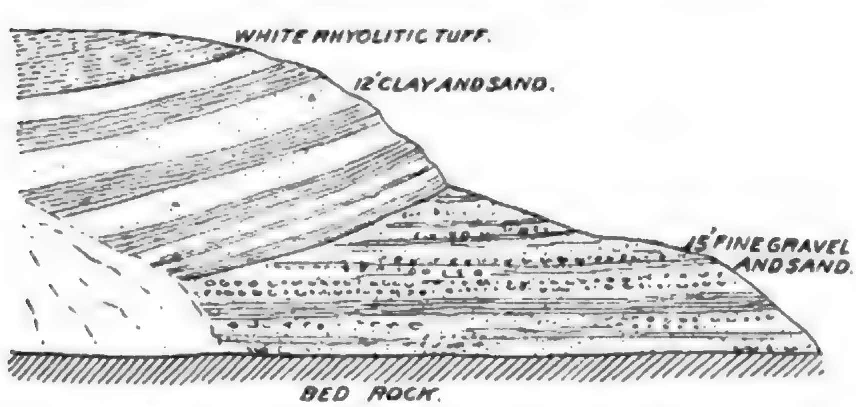


FIG. 5.—Bluff at hydraulic cut, near city reservoir, Nevada City.

rule, these flows consist of a detrital mass well cemented and made up of andesitic grains. Abundant angular or roughly rounded fragments of andesite of all sizes up to a foot or more in diameter are inclosed in this finer-grained mass. This andesite is of a gray to brown or reddish color, hardly ever greenish, and is usually distinctly porphyritic, with small crystals of white feldspar and black augite or hornblende. As a rule, it has a rough, trachytic appearance. Mica is rarely found.

Pyroxene (both augite and hypersthene) is almost invariably present. Black basaltic hornblende frequently occurs with the pyroxene, and usually in larger crystals. The groundmass is partly glassy, or of a very fine grained, holocrystalline structure. The thickness of the volcanic flows ranges from 400 feet in the Banner Hill district to about 200 feet in the Nevada City district. The easily disintegrating cement renders the exposures unsatisfactory, and a deep, reddish soil usually covers the tops of the ridges. This disintegration, and the tendency of the decomposed material and residual andesitic bowlders to slide downhill, often make the contacts with the underlying formations obscure and difficult to trace. Good exposures are found in the vicinity of the Harmony gravel mines. The best exposure, though practically inaccessible, is in the bluff of the Manzanita hydraulic pit north of Nevada City. Resting unconformably on the sloping surface of the white clays and sands, there are here at least four separate flows of andesitic tuff, each 20 to 30 feet thick and separated by irregular, worn

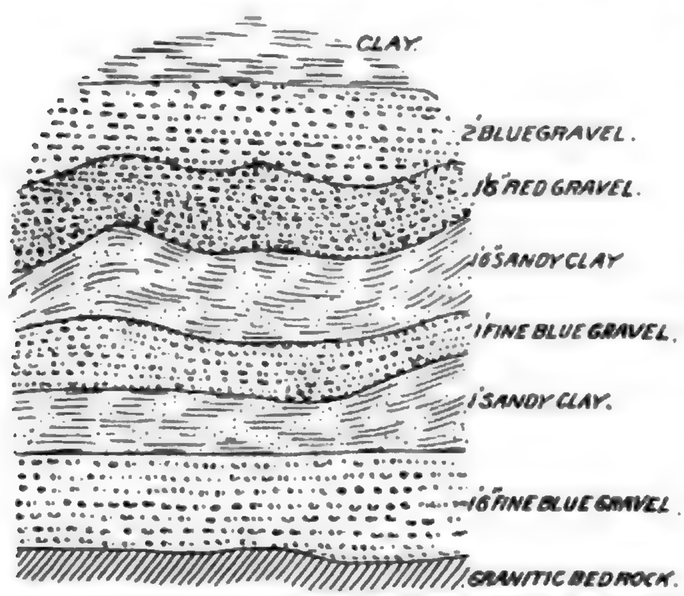


FIG. 6.—Section of breast of workings, West Harmony drift mine, 300 feet east of main drift.

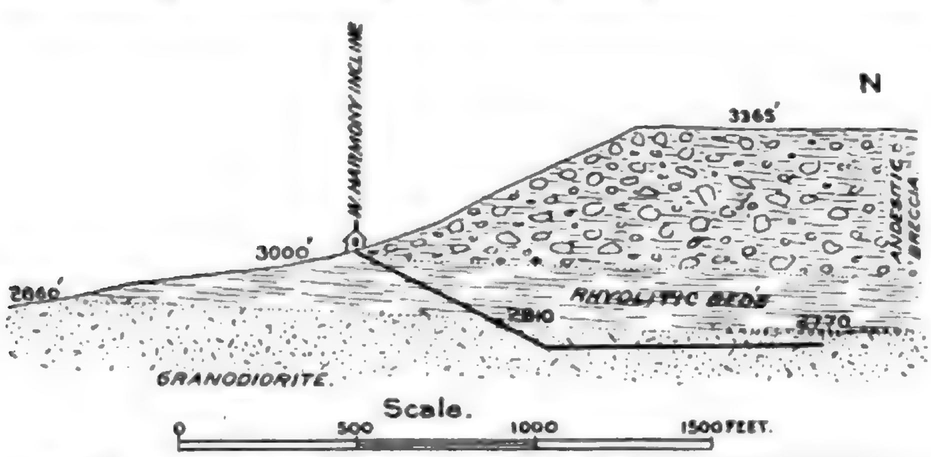


FIG. 7.—Vertical section along West Harmony incline, showing depth of formations and mode of mining.

surfaces. The amount of angular andesitic bowlders is not constant, and some flows consist entirely of the fine, detrital, cementing tuff. Of such character are the tuffs overlying the clays and gravels exposed in the hydraulic pit just north of Grass Valley.

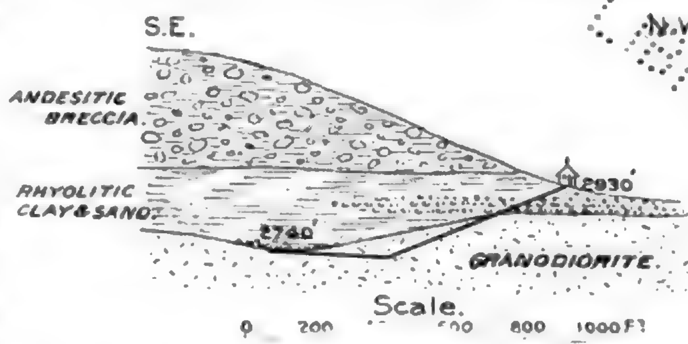


FIG. 8.—Vertical section along Yosemite incline.

ALLUVIUM.

The alluvial deposits are of small extent, and consist principally of a few gravel flats along Deer Creek, Little Deer Creek, and Wolf Creek. Many of these bodies of gravel are formed of débris from hydraulic gravel mines.

Alluvial sands and clays have accumulated in several swampy flats to the south and southeast of Nevada City, and also to some extent near the race-track. The largest alluvial deposits lie in Deer Creek below the Providence mine, and consist of well-washed gravel of quartz and metamorphic rocks, with some sand. They are made up largely of the débris from the extensive hydraulic mines just north of Nevada City, which had their principal outlet through the first gulch emptying into Woods Ravine from the east. In the Grass Valley district extensive flats of sand and clay occur on both branches of Wolf Creek above the city, and smaller gravel flats are found at intervals along the creek below the city. In the southwestern part of the district there are at the headwaters of the gulches a number of shallow alluvial flats of sand and clay, usually of a marshy character. The largest is found south of the North Star mine.

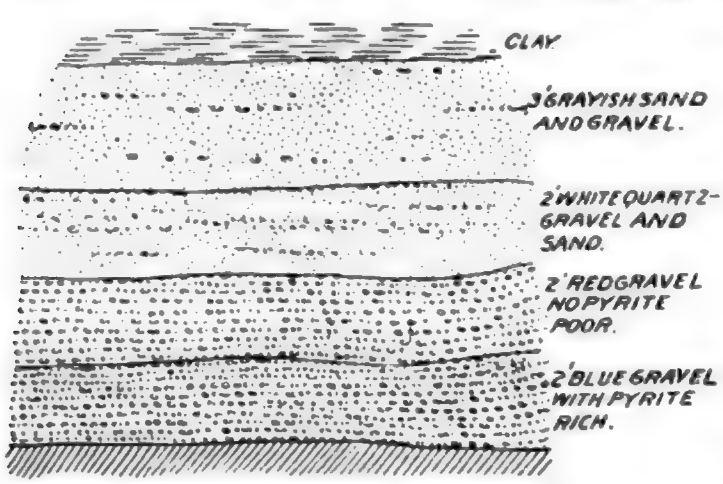


FIG. 9.—Section in workings of Odin drift mine.

CHAPTER VIII.

GEOLOGICAL HISTORY.

RÉSUMÉ OF HISTORY OF THE BED-ROCK SERIES.

With the knowledge acquired by the preceding more detailed study, the history of the bed-rock series may now be briefly reviewed.

The sedimentary series of the Calaveras formation are, without much doubt, the oldest rocks in the district. They comprise several subgroups of different character, and these may well be of considerably differing age. All that can be said definitely is that they antedate the Mariposa formation, and it is probable that they all are Paleozoic. No volcanic tuffs are found in these beds, though Paleozoic eruptives are known in this formation from other parts of the Sierra Nevada.

The formation was folded and strongly compressed long before the igneous rocks now associated with it had made their appearance. In the formation there is absolutely no evidence of synclines or anticlines, the compression having evidently reduced the series to practically parallel, extremely sharp folds, upon which a schistosity has generally been superimposed, in most cases apparently coinciding with the bedding. Subsequent intrusions have broken up this once-connected formation, and fragments of it are now contained in the later igneous rocks. The schistosity in the Calaveras formation of Nevada City and Grass Valley does not, then, necessarily correspond to the lines of disturbance in the bed-rock series developed subsequent to the granitic intrusion.

Then, after a considerable interval, probably followed the intrusions of the diorite-gabbro-pyroxenite group. The relations of this group to the other rocks is one of the doubtful points. On one hand, there seems to be an intimate relation between the granodiorite and the above-mentioned group, indicated by the occurrence of what may be transitions, and it is well known that the granodiorite may, close to the contact, pass into more basic allied rocks. Further, dike-like masses of serpentine and gabbro occur in the diabase and porphyrite, and even in the Mariposa formation (short distance above the Washington mine, upper Wolf Creek). On the other hand, there is clear evidence, from certain well-exposed places along the granodiorite-diorite contact, that the former is an intrusion into the latter, and there is excellent evidence afforded by dikes that the diabase and porphyrite are later than the diorite-gabbro group. On the whole, the probability is that the diorite-gabbro group of this district is older than both the granodiorite and the diabase and porphyrite. It is probably of the

same age as the gabbros and diorites of the foothills of Nevada County from Indian Springs northward, in which also dikes of diabase and allied porphyrites occur.

No very satisfactory evidence has been obtained as to the sequence within the diorite-gabbro group, but as far as it goes it seems to indicate that the basic rocks were the older and the more acid diorites the later parts of the intrusion. It is indeed not impossible that various parts of the gabbro and serpentine may be of different age, for it is well known that dikes of these rocks in other parts of the Sierra cut the Mariposa formation. In the text of the folio of the special sheets[1] it has been stated that probably none of the igneous rocks are older than the Mariposa formation. It is, however, necessary to admit that this is a very doubtful point in the case of the diorite-gabbro group. If the dikes of diabase and porphyrites occurring in it are contemporaneous with those similar rocks accompanying the Mariposa formation, it is certain that the rocks of the diorite-gabbro group at this vicinity were intruded before the Mariposa slates were deposited.

After this the eruptions and intrusions of diabase and allied porphyrites took place. This was not a local phenomenon, but similar igneous action occurred all along the foothills of the Sierra Nevada, resulting in the building up of volcanoes along the shore line to a height of many thousand feet above the present surface, only the interior parts and roots of which are now visible. During the earlier part of this widespread igneous action the late Jurassic Mariposa beds were laid down, and the tuffaceous rocks of this age contain abundant fragments of porphyritic rocks of an effusive type. The materials extruded during this period of intense volcanic action include, as is to be expected in a series of large volcanoes, rocks of both intrusive and effusive types. Basic rocks prevail, ranging in composition from medium-grained diabase to augite and hornblende porphyrites with cryptocrystalline groundmass; in the latter it is quite possible that some glass was once present, which is now devitrified; an extensive devitrification can certainly not be recognized. Rocks of moderate acidity occur to small extent in this igneous series, and are younger than the basic predominating rock, while very acid rocks or alkaline rocks are absent. Many of the effusive rocks correspond closely in mineralogical and chemical composition to the modern andesites.

After the deposition of the Mariposa beds and the close of the accompanying igneous activity, followed the important post-Mariposa orogenic disturbance. The Mariposa beds and tuffs were folded, compressed, and welded with the already compressed Calaveras formation. The igneous rocks were over large areas crushed and rendered schistose by intense dynamo-chemical metamorphism, while other areas escaped the pressure, which was chiefly concentrated along certain lines and belts of shearing. Within this period falls the formation of the Indian Flat and the Brunswick amphibolite belts.

[1]Geologic Atlas of the United States, Folio No. 29, Nevada City (Nevada City, Grass Valley, Banner Hill), Cal., 1896.

Now followed the last and farthest-reaching phase of igneous activity, in the form of the intrusion of enormous masses or batholites of granodiorite in the range, tearing asunder the older rocks and bending and twisting the older schist masses.

The intrusion must have taken place under great depth of overlying but now eroded rocks. Plainly shown as the fact is by geological investigation, the actual mechanical process almost surpasses our conception. In spite of the great pressure that must have been exerted by the intruding masses of granodiorite, it is not apparent that this pressure has produced any schistose structure on the surrounding rocks; the schistosity usually antedates the granitic intrusion, though in some cases it has been produced subsequent to it.

In this connection one fact deserves to be emphasized: There is absolutely no evidence of fusion of the surrounding masses accompanying these gigantic intrusions of molten magma; it should be expected in the Sierra Nevada if anywhere, but except very locally it is not found. This, as well as many other facts, throws great doubt upon the theory of genesis of igneous rocks by the fusion of sediments, a theory not without its adherents at the present day. Smaller masses of more basic material are frequently found along the contact of the granodiorite, showing evidence of earlier consolidation. Contact metamorphism affected many of the surrounding rocks to a width of up to a thousand feet; still larger contact-metamorphic zones are found adjoining the large granite areas of the higher Sierra.

The dynamo-metamorphic action continued after the intrusion of the granodiorite, but with less intensity, and evidences of this post-granitic disturbance are not noted in the special areas. Intrusions of small amounts of very acid, alkaline, and also of more basic magmas (aplites, quartz-porphyries, and lamprophyric dike rocks), followed the main intrusion of granodiorite and may be regarded as forms of differentiation of that magma.

The last phase of the history of the bed-rock series is the formation by compressive stresses of an extensive series of joint systems and fissure systems of differing directions, generally not coinciding with the old lines of dynamic disturbance. Along these joints and fissures ascending thermal waters deposited the ores and altered the country rock. Thus the hydrothermal metamorphism was the latest alteration to which the rocks have been subjected. Series of joints or sheeting parallel to the quartz veins are illustrated in Pl. III, opposite, and fig. 10 (p. 183).

The close of the granodioritic intrusion falls between the end of the Jurassic and the Chico Cretaceous, probably in the beginning of the Cretaceous period. At that time the Sierra Nevada must have formed a mountain range of imposing extent and elevation, in which the rocks now exposed at the surface were deeply buried.

SHEETED ZONE IN GRANODIORITE, MAIN STREET, GRASS VALLEY.

Dips toward the west

HISTORY OF THE SUPERJACENT SERIES.

THE GAP IN THE RECORD.

After the time of granitic intrusions and formation of quartz veins followed a period, including the latter part of the Cretaceous and the beginning of the Tertiary, from which no geological records are preserved, at least not in this vicinity. But there are indications elsewhere that the range during the whole time was a land area, and that the mountains of the early Cretaceous were subjected to long degradation, during which they were reduced at least to a condition of only moderate relief. Probably at the close of the Cretaceous the first break along the eastern margin took place, by which the Sierra Nevada was differentiated from the interior plateau and began to attain its present characteristic form. Erosion, invigorated, wore down broad valleys in the old plateau, and at some time during the beginning of the Neocene period the relative relief was such as the cast of the lavas covering it has largely preserved for our investigation to-day.

THE NEOCENE BED-ROCK SURFACE.

The Sierra Nevada was, in this latitude, a range of moderate height and relief, with a chain of prominent foothills, made up of the Jurassic lavas, with middle slopes characterized by broad river valleys and moderate relief, made up of the Calaveras slates, and with higher and more rugged summits made up of granitic rocks. Traces of the old Cretaceous plateau or the pre-Neocene peneplain are visible at intervals in the relief.

Excellent opportunities are offered in this district to study more closely the old Neocene surface. The areas covered by the Neocene deposits are numerous. The elevations along the contact lines and the data available from the underground exploration of the auriferous channels afford sufficient materials from which to construct a contour map of the Neocene surface (Pl. II). There are, of course, many spaces which must be filled in by suggestions obtained from adjacent areas, and many details may be incorrect, but it is very certain that the plate gives a generally correct conception of the Neocene topography. Of course, the map is affected by any subsequent deformation or tilting that the old surface may have undergone. Parts of the area where the data are insufficient have been left blank. The general features of the contour map show a prominent relief, but much less cut and scored by deep creeks and ravines than the modern topography. Banner Hill, the Town Talk Ridge, and Osborne Hill were then, as now, salient points of the topography. These eminences rose from several hundred to over a thousand feet above the deepest depressions. Banner Hill was, however, an unusually prominent point in this part of the comparatively gentle middle slopes of the Neocene Sierra, its hard siliceous

breccias strongly resisting disintegration. North of Banner Hill a prominent, high ridge of siliceous argillite divided the watershed of the Nevada basin from the main Yuba River, flowing from Scotts Flat northward toward Blue Tent and North Columbia.

West of Town Talk the drainage was clearly westward, down toward Rough and Ready. The Grass Valley tract in its northern part was drained by the Alta channel, heading northeast of Osborne Hill. There is no evidence that the channel continued eastward to Buena Vista slide, as stated in a previous publication.[1] Good proof of this is furnished by the fact that the rhyolitic tuff from the main Yuba channel also flooded the Buena Vista channel and the depression southwest of the Washington mine, but did not overflow into the basin of the Alta channel.

In the Nevada City district it is clear that the main depression was in the vicinity of Nevada City, for there the accumulations of gravel, sand, and clay are deepest and the elevations of the bed rock lowest. Up toward the highlands of Town Talk and Banner Hill the depth of the material mentioned grows less, and at a certain elevation the andesitic tuff rests directly on the bed rock. In the lower part of the basin the curious feature is presented of an almost continuous channel 4 miles long and practically level.

From Pecks diggings, at the head of Native American Ravine, at the northwest corner of the Nevada City tract, where the elevation of lowest bed rock is 2,650 or 2,660 feet, there is without doubt a continuous channel to the Empire shaft, with a lowest bed-rock elevation of 2,660 feet. Again, there is no reasonable doubt that the channel is continuous to the great hydraulic pits northwest of Nevada City, and here again the bed-rock elevation is 2,650 feet, even sinking to 2,625 feet in the vicinity of the old Merrifield mine. From here the lowest channel continues eastward over the exposed bed rock of the hydraulic ground, at elevations ranging from 2,630 to 2,640 feet. Again, at the southern end of the Manzanita channel the elevation is 2,645 feet. From the Manzanita pit the rich gravel on the bed rock, a few feet thick, has been drifted on up to the Odin mine, at which place the lowest bed rock is 2,655 feet. From the Odin incline the channel has been extensively prospected in the belief that it connected with the Harmony channel under the lava hill. The channel is here wider and the gravel of lower grade than farther south. At the Howe cut, where the channel emerges from under the ridge, the lowest bed rock has an elevation of 2,650 feet, though at the inner part of the cut a harder, granitic bed-rock ledge rises to an elevation of 2,670 feet. Such local inequalities are often met with in the old channels. There is thus no decided evidence to be derived from the grades as to the direction of the old channel.

[1] Bull. Geol. Soc. Am., Vol IV, p. 269. The channel at Buena Vista probably graded toward the east, to the main Yuba River.

Other facts show, however, that the Cement Hill channel, in the first place, must have flowed from the northwest to the southeast. First among them is the evidence from the gravel. At Peck's diggings there is only a few feet of imperfectly washed quartz gravel overlain by the clays and sandstones of the rhyolitic series, which here attain a depth of only 70 feet. At the diggings northwest of Nevada City the gravel is 60 feet deep, extremely well washed, and covered by from 150 to 200 feet of light-colored rhyolitic beds. This alone shows plainly enough that the direction of the channel was southeasterly. Regarding the other part of the channel, it has generally been supposed that it came down from the north, and that, bending about near Nevada City, its now eroded lower course followed the present valley of Deer Creek westward toward Rough and Ready. At the first glance this not only seems plausible but actually sustained by the grade of the channels, but there are very cogent arguments against such a supposition. In the first place, as in this vicinity the period of erosion between the rhyolitic beds and the andesite is insignificant, it should confidently be expected that some of the rhyolitic material would be found in the neighborhood of Randolph House and Rough and Ready, southwest of Nevada City, where fragments of channels are preserved. No such beds are, however, found there, the andesitic tuff resting directly on the bed rock or the gravel. On the other hand, presuming that the Manzanita channel did come from the north, we are confronted with the fact that the outlet of the Harmony channel at Laney's tunnel is somewhat lower than the bed rock at Howe cut, so that, on this supposition, in no way—the outlet being to the eastward of Howe cut—could any connection then have existed between these two channels. That the Harmony channel is continued toward the northwest to join the old Yuba River is clearly shown by the lower deposits at Round Mountain and the still lower fragment of channel preserved at Montezuma Hill. There would thus be no room left for headwaters of such a large channel as the Manzanita, on the supposition that it came from the north. Furthermore, the Manzanita channel was extremely rich in coarse gold. To the north of it are no quartz veins worth mentioning, while immediately to the south of it are the rich vein systems of Nevada City. On the west, toward the Providence mine, begin a series of much harder rocks, resistant to weathering, and which would easily form a barrier, just as the slate and diabase of Banner Hill, Federal Loan, and Town Talk still form barriers to the east and south.

The Manzanita channel then formed the central drainage of a flat depression in the easily eroded granodiorite, surrounded on east, south, and west by an amphitheater of rising hills. This drainage is indeed the most natural one to be expected in a vicinity where the tendency to transverse drainage is not so strongly developed as on the tilted plain of the modern Sierra Nevada. It has been shown in a former paper[1]

[1] Bull. Geol. Soc. Am., Vol. IV, p. 296.

that the grades of the Neocene river courses clearly indicate that such a tilting has taken place along an axis parallel to the crest of the Sierras, and that the amount of it, though not exactly regular over the whole slope, was 60 or 70 feet per mile as a maximum. Applying this principle to the Neocene drainage system of Nevada City, the difficulties are overcome, and the drainage becomes a very natural one.

The Cement Hill channel, with a direction from northwest to southeast, had then, before the tilting, a grade of 60 to 70 feet to the mile. The partly eroded channel between the western end of the big hydraulic pits and the Manzanita pit, which now has a slight grade of 20 feet westward, had before the tilting a moderate grade of about 50 feet per mile eastward. The channel between the Manzanita and the Howe cut, now practically level (excepting the hard projecting ledge at the latter cut), and which runs nearly due north, had before the tilting a slight grade northward of about 20 feet per mile.

From the Howe cut (elevation 2,650) to the lowest bed rock at Round Mountain,[1] 2½ miles due north, or 1 mile east of the line of tilting (elevation 2,625), there is a present grade of 10 feet per mile, which before the tilting was 30 feet per mile.

From Round Mountain to the lowest bed rock at Montezuma Hill (2,356 feet elevation, according to Pettee in Whitney's Auriferous Gravels), a distance of 2¾ miles in a direction nearly due west, there is now a grade of 100 feet per mile, which before the tilting would have been 30 feet per mile.

From Montezuma Hill down to French Corral, along Shady Creek and the present Yuba River, the only way which the Manzanita River could have followed, is a distance of 6 miles, with a present grade of 100 feet to the mile.

The Harmony channel must have joined the Manzanita a mile or two north of the Howe cut. The Harmony, coming down in a westerly direction, has now a very steep grade of about 150 feet per mile from the East Harmony to Laney's tunnel. Before the tilting it had a grade of about 80 feet per mile. East of the East Harmony the grade increases rapidly as the high ridge of siliceous argillite is approached. It has been held by many that the Harmony channel continues an indefinite distance up the ridge. This is impossible, as only a few miles eastward the deep Yuba channel, from South Flat to Blue Tent, crosses the ridge. The Harmony channel is well up toward headwaters, and under the Harmony ridge divides up into several branches. The subangular character of its gravel and the steep grades prove that the divide is not far distant. Its richness is not because of its being a main and important channel, but because of its crossing a system of rich quartz veins. It is barely possible that a deep gorge cuts through the ridge of siliceous rock and extends as far east as the Fountain Head, but it must be characterized as highly improbable. The vicinity

[1] See Geologic Atlas of the United States, Folio No. 18, Smartsville, Cal.

of the Fountain Head probably drained toward the main Yuba River eastward. There is, of course, no reason why auriferous channels should not be found on the east as well as on the west side of the divide. There is also a difference in elevation between the surfaces of the rhyolitic flows of from 200 to 300 feet between the vicinity of Cold Spring and Fountain Head. Such great difference would scarcely exist if there had been a communication between the two localities.

Considering the subsequent tilting, the Neocene bed-rock surface would originally have had a less sharp westward slope than is indicated on the map. Banner Hill, instead of rising to a height of 1,250 feet above the Manzanita channel, as now, would have had a height of only 1,050 feet above that point.

THE AURIFEROUS GRAVELS.

Having thus examined the surface on which the Neocene deposits rested, it remains to outline briefly the events that caused its burial under Neocene sedimentary and igneous deposits. At a period immediately preceding the volcanic eruptions of rhyolite and andesite the accumulations of gravel were not deep at any part of this area, located well up on the ridges dividing the main drainage lines. Along these main rivers, and principally along the great longitudinal valley of the Yuba from You Bet up to North Columbia, masses of gravel several hundred feet in depth had accumulated. One (though not the only) of the principal causes of this exceptionally heavy gravel mass is to be found in the fact that the Yuba River, flowing on the middle slopes in a broad and open valley, had to turn and force its way through the foothill range of Jurassic lavas in a relatively deep and narrow canyon, almost as deep as that of to-day and well shown by the present relations at Smartsville. This foothill range acted as a barrier, restraining the gravel masses in the open valleys of the middle slopes. In the Nevada City area the prevolcanic gravels reached the greatest depths along the Manzanita channel, and it is doubtful whether they have at any place exceeded a thickness of 40 feet. Rhyolitic fragments are found at that elevation above the bed rock, and even lower. It is doubtful whether the gravels, 60 feet thick, of the hydraulic pits northwest of the city are antevolcanic; the gravel is different from that generally found in the deepest parts of the Neocene channels, and has more the appearance of the extremely well-washed "black gravel" which appears at the higher elevation and which belongs in the rhyolitic period. Outside of the main drainage channel there was only a few feet of gravel on the bed rock along the streams, and in by far the greatest number of exposures the andesite or rhyolite rests directly on the bed rock. There is no reason to believe that the antevolcanic gravel in this vicinity antedates the Neocene period.

THE VOLCANIC FLOWS.

Such were the conditions when eruptions of enormous masses of rhyolitic tuffs began on the headwaters of the Neocene Yuba River. Their general character has been referred to above. It is probable that they were erupted as mud-flows, emerging from the crater mingled with much water, and that there was not only one but a long series of flows, in the intervals between which the older flows were to some extent worked over by the running water and interstratified with clay, sand, and gravels of local origin. These rhyolitic flows, 200 to 300 feet thick, are well exposed at Alta, on the Central Pacific Railroad, and at Chalk Bluff, near You Bet. At the latter place an extensive Neocene flora was collected by Mr. C. D. Voy and examined by Prof. L. Lesquereux.[1] The rhyolitic flows of Nevada City are the exact stratigraphic equivalent of the rhyolite tuff of Chalk Bluffs, and there can thus be no doubt about their age. Leaves similar to those of Chalk Bluffs occur at many places in the vicinity of the Manzanita channel, and with some trouble it may well be possible to obtain a good collection.

The tuffs are well exposed at Quaker Hill and Scotts Flat, farther down the Neocene river, and again on the north side of the Washington ridge at Blue Tent, at which place they are several hundred feet thick, the top stratum attaining an elevation of 3,000 feet. Near the place where the upper North Bloomfield road crosses Rock Creek, there was a low gap in the ridge between the main Yuba and the Nevada City basin; through this gap the rhyolitic tuffs poured into the granitic basin. It appears as if north of Blue Tent there was an obstacle, such as a narrowing valley, forcing the masses over the low divide in the adjacent drainage. The first flows found their way down into the Harmony and lower Manzanita channels, causing a damming of the latter, which again, of course, produced accumulation of sand and gravels in the upper part about Nevada City, and to this damming it is believed the heavy gravels of the Manzanita cut and Cement Hill are due. Subsequent flows found their way down to Round Mountain and Montezuma Hill, obstructing the channels to still greater extent. At last the whole of the lower part of the Nevada City basin became filled. The elevations of the top layers now range from 3,100 feet on the eastern side of the basin to 2,740 feet at the northwestern corner of the Nevada City tract, a distance of 5 miles from east to west. It will be noticed that on the supposition of a tilting of 70 feet per mile the surface would once, over this distance, have been approximately level, and about at the same level as the top stratum of the rhyolitic tuff at Blue Tent.

[1] The exact locality seems a matter of some doubt. It is not now accessible, having been covered by hydraulic débris. Professor Whitney states that the matrix is a rhyolitic tuff, but in the few specimens I examined, by the courtesy of Prof. A. C. Lawson, of Berkeley, the rhyolitic character is not clearly apparent under the microscope. At the locality I was told that the leaves were found in clay just below the white tuff and at the top of the extensive bench gravels of You Bet, several hundred feet above the bottom of the deepest channel.

The rhyolitic tuffs did not reach the southern and highest part of the Nevada City basin, nor did they overflow into the Town Talk or Grass Valley channel. To the east of the Neocene divide, rising along the eastern margin of the Grass Valley tract, the rhyolitic flows again appear, having reached there from the vicinity of You Bet. The divide was, however, just high enough to prevent this overflowing into the Alta channel.

As may be seen by tracing the contacts of andesite and rhyolite, the surface was not even, but subjected to some eroding action in the interval between the two eruptions; but it was not extensive enough to produce any marked change. In fact, those intervolcanic channels, cutting far down into the rhyolite, and even into the underlying bed rock, which are so characteristic of the vicinity of Forest Hill, Placerville, and Mokelumne Hill in the drainage of the Neocene American and Mokelumne rivers, are practically absent on the main Yuba, although on the headwaters of the North Yuba, near Forest City, they appear again. This is evidently caused by a differing time interval between the two eruptions; in this vicinity the first andesitic flow from the Lola and Castle Peak volcanoes followed closely after the last eruption of rhyolitic tuff.

During the latter part of the rhyolitic period many divides were flooded and the drainage was partly changed. The great Neocene orogenic movement of the Sierra probably took place between the rhyolitic and the andesitic eruptions, as is evidenced by the intensely eroding character of the cement channels or intervolcanic channels. A tilting took place, elevating the eastern part of the range most strongly and the western part but little. Flows of andesite tuffs, emerging from the craters as a mud, poured down the flanks of the Sierra in rapid succession, obliterating the old drainage and flooding many of the divides, Banner Hill and Osborne Hill alone emerging from the desolate lava plateau in this vicinity. On this inclined lava plain the rivers had to select new courses, in general differing considerably from the old ones. The present drainage was developed, characterized more than the Neocene by a transverse direction of the rivers.

CHAPTER IX.

THE ORES.

GENERAL FEATURES OF THE GOLD-QUARTZ VEINS.

Although gold is very widely distributed over the Sierra Nevada in veins and placer mines, there is no other part of it which shows such a concentration of valuable deposits within a narrowly circumscribed area as occurs in the districts here discussed. Almost the only form which the primary deposits of the bed-rock series present in this locality is that of quartz veins, consisting of fissures of somewhat different though closely related character, filled more or less continuously by quartz carrying native gold and auriferous metallic sulphides. These fissures, belonging to several systems, are usually traceable on the surface by means of the often harder, projecting quartz croppings, and attain a maximum length of a few miles; by far the most, however, can be traced only a few hundred or a thousand feet. In some localities the extremely decomposed surface rock and the narrow character of the veins render the tracing of the outcrop a most difficult undertaking, in which the miner's pan is an indispensable adjunct, for all quartz in these districts contains gold, though it may be present in very small quantities.

There is in some quarters a widespread belief that the veins of Nevada City and Grass Valley are in some way connected with the long, continuous linked veins of the Mother lode. This is a mistake, for the last branches of that vein system are found about 20 miles south of Grass Valley, and, moreover, the veins of Grass Valley and Nevada City differ considerably in their general character from the veins of the Mother lode.

With some notable exceptions they are narrow and produce a comparatively high grade of ore. They contain, as a rule, a much larger per cent of gold than of silver (by weight); the free gold is the most important constituent in the depth as well as on the surface, but besides there is a variable amount of gold and silver in the sulphurets.[1] The strike varies to all points of the compass; the dip is usually flat and also equally variable in direction. With all these different directions it is, however, easy to distinguish two main systems, north-south and

[1] This word, extensively used in the mining regions, has been adopted in this report to designate all the metallic minerals occurring on the gold veins excepting the native gold, thus including the simple and compound sulphides and arsenides as well as tellurides.

east-west veins. In the former system the veins may dip either east or west; in the latter, north or south.

The mines of the Grass Valley district have been and are especially productive; next in production follows the Nevada City district, and the Banner Hill district comes third. A large proportion of the production has been derived from a few prominent veins, such as the Eureka-Idaho, Rocky Bar, North Star, Empire, and Providence.

A type of veins different from the ordinary gold-quartz veins, though not of much practical importance, occurs in Grass Valley, and is characterized by pyrrhotite and chalcopyrite in a gangue of calcite, quartz, and feldspar. (See Crown Point mine, detailed description, Chapter XVI.)

OTHER DEPOSITS.

Though the quartz veins in their different forms constitute the only primary gold deposits of the districts under consideration, there are in Nevada County a few somewhat differing types of deposits of which brief mention may be made. The Pine Hill gold deposit,[1] about 10 miles south of Grass Valley, is characterized by a zone of intense thermal decomposition resulting in the formation of kaolin, a mineral practically unknown from Nevada City and Grass Valley, as well as masses of secondary quartz resulting from the decomposition of the porphyrite in the vicinity. There are abundant veins of barite, also unknown from the mentioned districts, and a little pyrite. The finely distributed gold contains much silver. This deposit has doubtless been formed by chemical action widely different from that characterizing the normal veins.

From Sweetland, a town on the ridge between the Middle and South Yuba, there extends down to the Yuba River, northwest of Nevada City, a narrow belt of fine-grained, amphibolitic slates altered to sericitic schists containing abundant pyrite. This pyrite carries gold, which is set free by surface decomposition; the rock has been mined and milled at the Boss mine near Sweetland. The streak is well exposed on the Yuba River. This process again would, on the whole, seem to have been identical with that by which the normal veins have been formed, and the only difference is that, in the case of the Boss schists, practically no quartz has been deposited, the solutions penetrating the schists, which were crushed to some extent, but without any notable open spaces.

Another streak along which impregnation of auriferous iron pyrites has taken place extends in the acid granodiorite and allied rocks from near French Corral across the Yuba River at the mouth of Owl Creek.[2] Here, too, the decomposed rock has been mined and milled, though of very low grade. The mineralogical character of this zone appears different; there is no extreme thermal decomposition of the

[1] Am. Jour. Sci., Vol. XLII, 1892, p. 92.

[2] Cf. Geologic Atlas of the United States, Folio No. 18, Smartsville, Cal.

rock, which is impregnated with pyrite in grains and along seams, and there is apparently no notable development of sericite. Instead, the pyrite appears to be connected with epidote, which would show a closer connection of this deposit with the general metamorphism than with the vein deposits in which epidote is unknown.

MINERALOGY OF THE VEINS.

GANGUE MINERALS.

Quartz.—The quartz occurring on the veins is generally massive, of a milky-white color and a luster between glassy and fatty. A grayish, very glassy quartz is considered an indication of poor ore. This milky-white quartz is, as thin sections show, usually made up of large, very irregular grains, occasionally with partly developed crystal faces. Sometimes the crystal faces show more plainly, and from this there are transitions to the well-known interlocking comb structure. This, however, in its typical form, is not very common. In the Osborne Hill and Centennial mines a radial structure of the massive quartz is sometimes noted. Fluid inclusions are abundant, though small, and usually irregularly distributed. Well-developed crystals are not common, and are chiefly found in small cavities or vugs in the massive quartz. Certain veins, such as the Granite Hill, are of very drusy character, long, imperfect crystals coating the walls and radiating from fragments of the country rock. All of the ore minerals subsequently to be described occur as inclusions in the quartz.

Opal and chalcedonite.—In several mines small quantities of a brownish chalcedonite, extremely fine grained in structure, occur with the quartz. Often it is of such deep-brown color as to be hardly translucent in thin section. It is found as irregular masses in the quartz, or as veinlets cutting through it, or again, as at the Osborne Hill mine, filling cavities and surrounding projecting quartz crystals. Gold directly embedded in the chalcedonite has been found on the 600-foot level in the Rush and Laton shoot, Empire mine, and 140 feet below the surface in the Hudson Bay shaft. Professor Blake reports "grayish-blue or white opal, probably allied to cacholong," from the North Star mine,[1] while Professor Silliman mentions chalcedony from Massachusetts Hill, Allison Ranch, Kate Hayes, and Eureka mines.[2]

Calcite.—Calcite occurs in small quantities on every vein in the district. In the decomposed country rock adjoining the vein it is very abundant, though always in massive granular form. In the quartz it occurs frequently as small particles not easily visible to the naked eye; occasionally, also, as larger masses, of white color, breaking into good-sized cleavage pieces—for instance, in the Spanish mine and in the South Idaho. Crystallized calcite is occasionally found in cavities in

[1] Pacific Railroad Report, Vol. V, p. 268.
[2] Am. Jour. Sci., Vol. XLIV, 1867, p. 236.

the quartz; small scalenohedrons (R3) were noted from the Providence mine; larger, short, and thick crystals, combination of $-\frac{1}{2}R$ and a steep scalenohedron, with several subordinate faces, occur in the Empire mine, twentieth level.

The calcite in the wall rock of the vein generally contains some iron and magnesium.

Magnesite occurs nearly pure, as a product of alteration of serpentine, in the Idaho and Maryland mines.

Sericite.—This is a form of muscovite, or white mica, extremely common as microscopic aggregates in the altered wall rock, but the individual foils are hardly ever visible to the naked eye. The white color and greasy feel of many of the altered wall rocks are due to this mineral.

Mariposite.—This is a bright-green, foliated mineral closely allied to muscovite. The green color is due to a small percentage of chromium. It occurs in small quantities in magnesite or quartz in the Idaho-Maryland mine. A little of it was also noted from the Providence mine. Generally it appears to be a product of alteration of serpentine.[1] There appears to be no good reason for separating it from fuchsite or chromiferous muscovite.

Scheelite.—This mineral, a tungstate of calcium, is stated to have occurred in considerable quantities in the foot wall of a mine on Howard Hill, Grass Valley.[2] This is interesting, if authentic, being the only occurrence of tungsten in the district.

ORE MINERALS.

Native gold.—Metallic gold is contained in all quartz veins of this region in smaller or larger quantities. The most common form in which the gold appears is that of minute flakes and particles, as a rule not visible to the naked eye. To this there are, however, numerous exceptions. In several mines a large part of the gold is in the form of larger leaves, sheets, or masses. The Grass Valley veins carry, as a rule, more coarse gold than those of the Nevada City tract. A small vein will usually carry more coarse gold than a large one, and in certain seam mines the gold may occasionally appear as a sheet filling the entire seam, with but little quartz. Massachusetts Hill and Gold Hill, Grass Valley, were noted for the heavy masses of gold extracted from their veins. A specimen from the Crown Point mine, Grass Valley, contained in a 3 or 4 inch vein of quartz and calcite in serpentine at least $200 in heavy, massive gold. The coarse gold is rarely crystallized, and the forms, where occurring, are rude and distorted. Beautiful leaf gold sometimes occurs in cavities coated with quartz crystals; for instance, in the Granite Hill vein, Grass Valley. Mr. Melville Atwood states[3] that in 1859, in the mine of North Gold Hill, he

[1] For analysis, by Hillebrand, see H. W. Turner's article on the gold ores of California, in Am. Jour. Sci., Vol. XLIX, May, 1895.
[2] Fourth Ann. Rept. State Mineralogist of California, p. 353.
[3] Eighth Ann. Rept. State Mineralogist, p. 774.

took out a pocket of many thousand dollars' worth of gold, all in leaf-shape form, with beautiful quartz crystals, and they were all embedded in a decomposed ferruginous matter. The gold is chiefly contained in the quartz; only once, in a specimen from the South Idaho mine, was it noted in calcite. Occasionally, but very rarely, visible particles of it occur in the altered wall rock adjoining the veins.

A close association of the gold with the patches of sulphides occurring in the quartz is often noted, and sections will often reveal larger and smaller irregular particles of gold contained in the galena, iron pyrites, arsenical pyrites, zincblende, or tellurides.[1] (Pl. V, fig. *c*.) Generally, however, the sulphurets are auriferous even when it is impossible to detect any metallic gold in them with the microscope. It is probable that the gold is here, as in the quartz, in a metallic state, distributed in extremely minute particles.

All quartz gold contains, as is well known, alloyed silver. In the majority of the veins of this district the fineness ranges from 800 to 860. In the Willow Valley east-west veins the amalgamated bullion is less pure, generally about 750 fine. In Canada Hill the gold averages 730. In the Lecompton and the Federal Loan mines the bullion has been observed as low as 650 and 670. This should probably not be taken to indicate that the native gold contains 350 parts of silver, for the ore may have contained easily amalgamated, rich silver minerals, and arsenic and antimony may also be contained in the bullion. In fact, a specimen from the Beckman vein, at Canada Hill, of which the amalgamated bullion is only 750 fine, contained abundant, easily visible, bright-yellow gold equally distributed in the quartz, galena, and blende.

The North Star vein, as well as the veins of Massachusetts Hill and Gold Hill, contains high-grade gold, averaging 850 and sometimes reaching 875.[2] The Seven-thirty mine reports gold 950 fine, which is very unusual. The Merrifield and Providence veins contain gold averaging 800 fine. In the Osborne Hill veins, which carry much arsenical pyrites, the gold averages 760 to 775. In the Empire mine, belonging to the same system, the fineness is about 800. In the Eureka-Idaho vein it is 848.

Electrum, a pale-colored alloy of gold and silver, with more than 25 per cent of the latter metal, has not been noted.

Gold amalgam.—Mr. C. Hesse, superintendent of the Odin drift mine, obtained from samples of fresh undisturbed gravel, taken on the bed rock of the channel and washed in the pan, a number of small but well-rounded, white, metallic grains, associated with the gold, and which proved to be gold amalgam. Its occurrence and appearance admitted of but one explanation—that it had the same origin as the gold and once occurred in a quartz vein of the vicinity. Some of the flat, rounded grains consisted, as shown under the microscope, partly of gold, partly of amalgam.

[1] Gold in pyrites and galena noted from the Omaha mine; gold in arsenopyrite noted from the Betsy mine; gold in zincblende noted from the Mayflower and Grant mines; gold in altaite noted from the Providence mine.

[2] Compare Fourth Ann. Rept. State Mineralogist p. 222.

Tellurium minerals.—Tellurides are probably more common than has been suspected, but it is only rarely that they occur in quantities large enough to be mineralogically determined.

A telluride of silver, presumably *hessite*, lead-gray, soft, and somewhat sectile, was identified by Dr. W. F. Hillebrand in a specimen from the Nevada City mine, occurring with pyrite, galena, and native gold.

Altaite, a telluride of lead and silver, tin-white, with a yellowish tinge and sectile, was also identified by Dr. Hillebrand from the Providence mine. It occurred in considerable quantities as a bunch in the Ural vein of that mine, in the stopes between the 600-foot and 1,200-foot levels. It was associated with quartz, pyrite, galena, and abundant native gold, the latter intergrown with the tellurium mineral.

In testing samples of the concentrated sulphurets from several mines for tellurium, a negative result was usually obtained. The element was found in small quantities in the concentrates of the Nevada City and Providence mines. A remarkably large percentage of tellurium was found in the Idaho-Maryland concentrates, amounting to 0.03 per cent; there have been no tellurides noticed thus far in the ores of that mine. Tellurium is also said to occur in the ore of the Charonnat or Canada Hill mine.

Tetradymite, or telluride of bismuth, is doubtfully reported from the Murchie mine,[1] and Mr. J. J. Ott, of Nevada City, states that a tellurium mineral was certainly found at that mine. It is worthy of note in this connection that a small quantity of bismuth was found in the concentrates from the Providence mine.

Pyrite.—This mineral occurs on practically every vein in the district, both in the quartz and in the altered country rock. In the quartz the mineral is usually found in massive form, intergrown, without recognizable succession, with other metallic minerals. Imperfect crystal forms are often recognized, though well-developed crystals occurring in cavities are rather uncommon. The forms shown are always a combination of cube and pentagonal dodecahedron. In the altered wall rocks sharp, though usually small, crystals are extremely common, and the cubical form predominates. Excellent and sharp cubical crystals up to 1 cm. in diameter occur in a soft chloritic rock on the dump of a shaft on the Kentucky claim, some distance east of the Maryland. Pyrite is the most abundant of the "sulphurets" in the quartz veins, and generally makes up from 80 to 90 per cent of the concentrates.

Small masses of pyrite, intergrown with epidote and magnetite, occur in diabase in the tunnel on the Star Placer mine, west bank of Wolf Creek just above the Omaha mine.

Marcasite.—This mineral, the orthorhombic form of iron disulphide, does not appear to occur in the quartz veins. A very pale yellow pyritic mineral found on the dump of a tunnel 1,800 feet south of the Golden Treasure mine was at first thought to be marcasite, and a statement to this effect was made in a paper on the "Characteristic

[1] See Eighth Rept. State Mineralogist.

features of California gold-quartz veins."[1] Professor Penfield, to whom the specimen was shown, considered it, however, as pyrite with a marked octahedral parting, and Professor Pirsson kindly measured the fragments, finding angles closely approaching those of the octahedron. Such an octahedral parting has not been previously observed in pyrite.

In the blue gravel from the bottom of the Neocene channels concretions of iron disulphide often occur, sometimes cementing quartz grains and pebbles. From the pale color and strong tendency to decomposition exhibited, it is probable that this is marcasite.

Pyrrhotite.—This mineral, also known as magnetic pyrite, occurs sparingly, but not, so far as known, on any of the normal gold-quartz veins in this district. It is contained as a primary constituent in certain diabases of Grass Valley, and as a secondary mineral impregnating many metamorphosed rocks (in hornfels near the Federal Loan, in porphyrite-breccia on Banner Hill). Larger masses of it were found in a seam a short distance north of the Crown Point mine. It is here associated with chalcopyrite, pyrite, and calcite, with very little quartz. According to Dr. Hillebrand, it contains only a trace of nickel.

Chalcopyrite.—Nearly all of the quartz veins contain this mineral, but only in small quantities. It rarely makes up more than 3 per cent of the sulphurets in the quartz. The Providence, Champion, and Nevada City mines, and especially the Idaho-Maryland, carry the largest quantities of it. It is very rarely crystallized. A little chalcopyrite is also found disseminated in certain metamorphosed diabases and porphyrites.

Galena.—This is almost universally present in quantities about equal to the chalcopyrite. It forms grains and irregular masses in the quartz, and is rarely if ever found crystallized. It is frequently rich in gold, and is always considered a "good indication."

Sphalerite (*zincblende*).—This mineral is extremely common, and occurs in the quartz on almost every vein in the district. The Providence concentrated sulphurets contain 1.6 per cent of zincblende, and in the Beckman vein, Canada Hill, the percentage is still greater. The Idaho-Maryland vein, on the other hand, contains extremely little of this mineral. The zincblende is usually black, with a greenish tinge. In the Alpine tunnel, Canada Hill, a pale-yellow variety occurs, together with the former. In the Beckman vein and in the Osborne Hill mine the blende is reddish-brown, and often very rich in gold.

Arsenopyrite.—This mineral is very common, but somewhat irregularly distributed. It occurs both in the quartz and in the adjoining altered country rock, and seems, in fact, to prefer the latter. When in larger accumulations it is mostly massive, but it exhibits a great tendency to form minute and extremely sharp crystals when occurring disseminated in the country rock or in the quartz. Beautiful, though small, crystals, long and slender and formed by a combination of prism and base, are found in the Osborne Hill vein. Most of the veins in the Banner Hill tract contain abundant arsenopyrite, the Federal Loan

[1] Bull. Geol. Soc. Am., Vol. VI, p. 231.

leading, with about 18 per cent in the concentrated sulphurets. On the other hand, the Providence-Champion-Nevada City complex of veins carries very little of this mineral, a sample of Providence concentrates containing only 0.012 per cent. In the Grass Valley tract the percentage of arsenopyrite in the veins is usually very small, excepting the Osborne Hill system, which, from the Orleans mine south, carries considerable quantities of it. The veins of Forest Springs, 4 miles south of Grass Valley, also carry much arsenopyrite.

Pyrargyrite, stephanite, and argentite.—These rich silver minerals have been identified in a specimen from the Allison Ranch mine, in the United States National Museum (No. 14967). Besides these minerals, the specimen contains much pyrite, chalcopyrite, and galena. Pyrargyrite has also been found in the Central mine, south of Banner Hill. The relatively large quantity of silver found in the concentrates of certain other mines, for example, the Providence, Champion, and North Banner, indicates the possibility of rich silver minerals occurring in a finely divided state in them.

Tetrahedrite (fahlerz).—On a vertical cross-vein cutting across the Osborne Hill vein, near the shaft, on the fourth and fifth levels, a heavy mass of tetrahedrite was found carrying 1 per cent of silver. The mineral was associated with yellow zincblende and chalcopyrite. It is also reported from the North Banner mine,[1] and probably occurs in small quantities in many other mines in the Banner Hill and Willow Valley districts.

Molybdenite.—In the California gold-quartz mines this mineral is by no means uncommon. It has been found, inclosed in quartz, in the North Banner mine; in a nameless vein, nearly barren of gold, in the Mayflower ground; and in the Merrifield and Ural veins, at the Providence, Champion, and Nevada City mines. It usually forms bunches, and is apparently not intimately associated with the other sulphurets; it is not known to be auriferous. When occurring abundantly it makes the pulp in the battery black and slimy, and interferes with the amalgamation on the plates. It is easily mistaken for graphite.

Cinnabar.—While no cinnabar has yet been found in any quartz vein of the district, the fact deserves mention that according to Mr. J. J. Ott, of Nevada City, grains and pebbles of this mineral were at one time found in the sluice boxes of the Manzanita hydraulic mine. Taken in connection with the above-mentioned occurrence of amalgam, it may be considered certain that one or several of the veins in the Nevada City tract contained quicksilver. The association of quicksilver and gold has frequently been noted in the Gold Belt.

PRODUCTS OF SURFACE DECOMPOSITION.

Limonite, or brown iron ore, is common in the decomposed quartz of the upper levels in most of the mines. As is well known, it is a result of the surface decomposition of pyrite.

[1] Eighth Ann. Rept. State Mineralogist, p. 421.

A *hydrous sulphate of aluminum* occurs as a deposit from spring waters in the Providence drain tunnel, in part colored blue by copper.

Azurite and *malachite* result occasionally from the decomposition of chalcopyrite.

MINERALS NOT CONNECTED WITH THE QUARTZ VEINS.

Copper.—Metallic copper in small rounded crystals was also found in the gravel of the Odin mine. The crystal form indicates that the copper was probably precipitated from solution by reducing influences in the blue gravel and the crystals formed in the gravel. Whitney[1] mentions native copper occurring in the Tertiary channels.

Magnetite.—A small deposit of magnetite with some quartz is found in the diabase, near the granodiorite contact, 4,000 feet east of the Omaha mine, in Diamond Creek. The exact nature and extent have not been ascertained. There are within the foothills of the Sierra Nevada several similar deposits, some of large size, and always occurring in diabase or slate, close to the contact with the intrusive rock. These occurrences are probably in genetical connection with the intrusive rock and possibly formed by contact-metamorphic action.

Scattered fragments of magnetite are also found near the dry reservoir 1,700 feet east of the railroad station at Grass Valley, and not far from the granodiorite contact.

Magnetite also occurs with epidote and pyrite, as probably segregated masses leached from the surrounding rock, in the tunnel of the Star placer mine, 1,650 feet north of the Omaha mine.

Earthy manganese ore (*pyrolusite* or *wad*) occurs often in small fissures in the granodiorite near the surface. It was especially noted in the vicinity of the North Banner mine.

A similar manganese mineral was found as a concretion in the West Harmony drift mine, cementing grains of quartz.

Garnet.—This mineral is evidently very rare in this district. Brownish massive garnet was noticed, probably as a product of contact metamorphism, in a specimen of amphibolitic rock collected in a little gold by the road, 1,600 feet west of the North Banner mill.

Wollastonite.—A specimen of wollastonite in hornfels was found on the Old Banner dump. This mineral also is undoubtedly due to contact metamorphism.

Chabazite.—At the tunnel of the Star placer mine mentioned above crystals of chabazite were found coating small fissures in an altered diabase, filled with epidote and pyrite. The crystals are several millimeters in diameter, colorless, and of the well-known pseudo-cubical form.

THE MINERAL WATERS ON THE VEINS.

General features.—The ordinary mine water contains only a small amount of dissolved substances, and is evidently meteoric water of the superficial circulation. In a few instances, however, strong ascending

[1] Auriferous Gravels, p. 366.

springs are found on the quartz veins. These springs, though neither very rich in dissolved materials nor of a temperature differing from that of the inclosing rocks, form a deposit at the point where they issue, and their composition is of interest as in some degree indicating the nature of the springs to which, in all probability, the veins owe their origin. Two such ascending springs were noted and their waters and deposits examined.

The Federal Loan mine.—The first is in the 400-foot level of the Federal Loan mine, about 400 feet east of the shaft. The water issues from a crack in the foot wall about 5 feet up from the bottom of the drift, the quantity being about 2 gallons per minute. A considerable quantity of yellowish-white, slimy deposit was, at the time of my first visit, formed on the wall for a distance of 2 or 3 feet below the place where the water issued; the deposit did not seem to form on the bottom of the drift. At a second visit, when the water was collected, the work had been resumed in the drift, the face of which was only a few feet from the spring, and the deposit had been swept away. Mr. George A. Treadwell, of Nevada City, had previously collected a bottle of the substance, which he kindly placed at my disposal. An unmistakable odor of sulphureted hydrogen was noted in the vicinity of the spring. A sample of 2 liters of the water was filtered and bottled in the mine.

The Mountaineer mine.—The second locality is in the Mountaineer mine (Nevada City sheet), on a hanging-wall vein called the Black Prince, about 170 feet east of the main fissure. The spring appears in the foot wall on the 400-foot level, south of the shaft, tastes strongly of iron, and forms a heavy yellowish-brown deposit. There was no odor of H_2S in the vicinity of the spring.

The waters were analyzed by Dr. W. F. Hillebrand, with the following results:

[Parts per million (grams per ton).]

	Federal Loan.	Black Prince.
SiO_2	32.70	41.40
Cl	3.16	3.10
S	1.10	....
SO_4	7.70	7.80
CO_3	141.80	146.60
Pb	Trace.	Trace?
As	None.	Trace?
Fe_2O_3 / Al_2O_3 }	4.20	1.80
Mn	.27	1.90
Ca	33.60	44.35
Mg	5.70	3.35
K	1.00	1.60
Na	13.40	13.70
H_2 (for bicarbonates)	4.60	4.70
	249.23	270.30

NOTE.—Organic matter present in small quantity in both waters.

Dr. Hillebrand remarks on these waters as follows:

Both waters showed an alkaline reaction, and that from Federal Loan gave also a test for sulphides in solution after filtration. The Federal Loan water contained a small amount of black flocculent deposit, chiefly silica colored black by iron sulphide, so far as could be made out. The Black Prince water contained a large amount of similar black deposit containing much iron sulphide and, perhaps, ferric hydrate. No test for soluble sulphides resulted definitely in this sample, but there appeared to be a little hyposulphite (thiosulphate) in both waters. Hydrogen sulphide was not present in either. Since the waters were reported to be clear when bottled, it seems probable that the formation of soluble and precipitated sulphides may have been due to the reducing action on the sulphates of the corks, especially since the waters had been bottled many months, and the surface of the corks was thoroughly blackened. In view of the great uncertainty as to whether the present condition represented in important essentials that at the time of bottling, a very exhaustive or thorough analysis seemed unnecessary. It is to be noted that although the deposit formed by the water contains much arsenic it could not with certainty be detected in 2 liters of the water.

The waters are remarkably similar in composition, and may be characterized as weak mineral waters, chiefly distinguished by their percentage of silica and carbonates. There is, roughly speaking, from 33 to 41 parts per million of silica present, 175 to 226 parts of bicarbonates of calcium, magnesium, and sodium, and 12 to 14 parts of sulphates. Sodium is present in far larger quantities than potassium. Chlorides occur only in very minute quantity. Of carbonic acid there is hardly enough present to form bicarbonates with the bases. Hydrogen sulphide was certainly present in small quantities in the Federal Loan water at the time of bottling, although subsequent reactions probably masked its presence.

The composition of the deposit from the Federal Loan water is, according to Dr. Hillebrand, as follows, in rough approximation:

	Per cent.
$CaCO_3$	10.8
$MgCO_3$	
Mn (as MnO_3)	.6
As (as As_2O_5)	1.3
Fe (as Fe_2O with little Al_2O_3)	23.3
Insoluble and silica	18.4
SO_3	.5
Pb	Trace.
Organic matter and water	34.9
	99.8

Dr. Hillebrand makes the following remarks on this analysis:

The bottle was filled with a black slimy matter emitting a disgusting odor of organic decomposition. The cork was forced out with ease by imprisoned gas, chiefly consisting of CO_2 and CH_4. The slime was said to have been white when

collected; the subsequently developed black color is due to iron sulphide. Aside from organic matter and water the deposit is essentially ferric oxide with a little arseniate, calcium carbonate with a little magnesium carbonate, and manganese as MnO_2, besides gelatinous silica and fragments of minerals. Owing to reduction of sulphates with bottling and the presence of vegetable organisms, an accurate analysis could have no value, and the amount at disposal was also too small.

The presence of lead and arsenic in this deposit is of interest. The organic matter was abundant, and consisted of long, stringy fibers, evidently an algous growth, such as is so often noted at the mouths of mineral springs.

The deposit from the Black Prince was of brown color and in qualitative composition chiefly ferric hydrate with a little calcium carbonate and much less magnesium carbonate, also silica and insoluble matter and much manganese in a peroxidized condition. There was also a decided trace of molybdenum. No arsenic, copper, lead (?), nickel, or aluminum was detected, and very little sulphuric acid. Some organic matter was present.

The Providence mine.—A deposit found in the drain tunnel of the Providence mine, 800 feet from the mouth, is of quite different character. When dried, it formed dirty white masses of all degrees of fineness, from coarse lumps to an impalpable powder; some of it has a decided greenish tinge. Selected greenish pieces were analyzed by Dr. Hillebrand, with the following result:

	Per cent.
SiO_2	8.31
Al_2O_3	37.57
Fe_2O_3	.44
CaO	.12
MgO	Trace.
CuO	.57
Mo	Trace.
Na_2O	.17
SO_3	9.51
H_2O	42.98
	99.67

The water was determined as follows:

	Per cent.
Over H_2SO_4	15.16
At 110° C	8.39
Below redness	19.03
Blast	.40
	42.98

A general sample showed essentially the same composition, and contained, besides, MnO_2 in black grains. Some organic matter was also present.

The substance appears to be a mixture of a hydrous aluminous silicate and sulphate, and probably results from the leaching of pyritous ore by surface waters.

THE ORES.

GENERAL CHARACTER.

There are, in general, two classes of gold-quartz veins, between which, however, no distinct line of demarcation exists. The first embraces those veins in which the gold is nearly exclusively connected with the sulphides and is not easily removed from them by simple amalgamation and in which free gold is found only in the upper decomposed zones; in these veins there is usually also much silver. The other class, to which the veins here described belong, carry an ore of which the principal value lies in the free gold, the relative amount of which shows no diminution in depth once the surface zone of decomposition is traversed. The gold and the auriferous sulphides, some of which are always present, are embedded in a predominant quartz gangue and constitute almost exclusively the pay ore. The country rock adjoining the veins has in most cases been subjected to a more or less complete replacement by carbonates, sericite, and sulphides, but this replaced country rock is here, if not barren of gold, at least very poor. In certain deposits the quartz is distributed in minute seams and streaks in the decomposed country rock instead of forming a continuous, thicker sheet; in such cases the whole may be mined and milled, but the pay will generally be found to be concentrated in these narrow seams. In isolated cases the altered country rock may contain a sufficient quantity of gold to be treated as an ore. Instances also occur where a large quartz vein is nearly barren but the seams in the adjoining altered rock are rich in gold.

THE GOLD.

As stated before, the gold is, speaking generally, in a finely divided condition and scarcely visible to the naked eye, and it is a well-known fact that sometimes a notable quantity of it is carried away suspended with the finest slimes from the mill, even in the overflow from the settling tanks, if such are used. Much of the gold in the narrow Grass Valley mines is, however, quite coarse; in several mines, as the North Star and the Empire, bunches of quartz containing coarser gold are found in the pay shoots, generally carrying fine gold. The intimate relation between the gold and the sulphurets is emphasized above and illustrated on Pl. V, fig. *a*.

THE SULPHURETS.

Quantity.—The sulphurets generally make 2 to 3 per cent of the ore. In the Willow Valley district there is quite generally a stronger percentage, ranging from 4 to 6 per cent. The same conditions obtain in the Banner Hill and Mayflower group of veins. The veins in the vicinity of the Pittsburg and Gold Tunnel group of veins, except the Pennsylvania, carry a less amount. In the Providence-Champion group the percentage is high, ranging from 4 to 6 per cent, but the same veins in their northward extension carry less again. The Idaho system of east-west veins carry little sulphurets, as do also the Empire-Osborne Hill system and the W. Y. O. D., the percentage ranging from three-fourths of 1 to 3 per cent. The Eureka-Idaho vein shows, on the whole, the smallest percentage, ranging from three-fourths of 1 to 2 per cent. The Massachusetts Hill and Granite Hill veins, as well as the North Star, carry from 2¾ to 3 or 4 per cent. The Omaha system carries about 4 per cent.

In comparing these data no definite law can be deduced as to the percentage of sulphurets in different country rock. The largest percentage is found in granodiorite, in certain veins in the sedimentary areas, or on the contact of both formations; a medium to small percentage occurs in diabase and porphyrite and in serpentine. Numerous exceptions make this rule of doubtful value. Some veins of the Mayflower system in slate and some mines in granodiorite, such as the Gold Tunnel and California, contain comparatively little sulphurets.

Equally doubtful results are obtained in comparing the percentage of sulphurets in the various vein systems. The only rule that might be adduced here is that the veins of the Idaho system in Grass Valley are poor in sulphurets, but against this stands the fact that the parallel Orleans vein near Nevada City is in places rather rich in them.

Character.—On nearly all veins pyrite predominates; the exceptions are certain mines in Willow Valley and the vicinity of Canada Hill, where arsenopyrite or zincblende (Beckman vein) prevails. In the Merrimac and Union veins galena is said to prevail. In nearly all veins there is, besides pyrite, galena, zincblende, and chalcopyrite. The veins with arsenopyrite are confined to certain localities, as indicated in the pages on mineralogy, but not to any certain kind of vein or country rock. In fact, any attempts to correlate the character of the sulphurets with the country rock appears a failure. Certain veins in granodiorite contain no arsenopyrite; other veins in the same rock show this mineral in large quantity.

Contents of gold and silver.—The sulphurets in the quartz always contain gold and silver. Those from the altered country rock also contain some, but are generally much poorer. The concentrated sulphurets, which are not quite pure, but contain a certain quantity of quartz,

varying from 5 to 15 per cent, range in value from $40 per ton to several hundred dollars, chiefly in gold.

In any given mine the tenor of the sulphurets generally increases with the richness of the ore. It is found, however, that in many of the Grass Valley mines, which carry rich ore with much free gold, the concentrates are relatively poor. In the Providence and Champion veins, the ore of which is of lower grade, the sulphurets run high in gold, probably averaging not less than 5 ounces per ton. The sulphurets of the great Eureka-Idaho ore shoot are uniformly rich, ranging from 5 ounces of gold per ton upward.

The relative quantity of silver varies also, but only in few mines exceeds that of gold by weight. In most of the sulphurets of the Banner Hill district there is a considerable quantity of silver, probably reaching its maximum in the Banner mines, where the quantity of silver greatly exceeds that of gold and sometimes almost equals it in value. The Federal Loan sulphurets, on the other hand, carry only about 2½ ounces of silver per ton.

In the Nevada City district the greatest percentage of silver is found in the Mountaineer, Merrifield, and Ural veins; at the Champion and Providence mines the sulphurets contain from 10 to 16 ounces of silver per ton, or more than double the amount of the gold. But at the Nevada City, on the same vein, the percentage of silver sinks, and equals or is less than that of the gold.

In the Grass Valley district there is generally only a small quantity of silver in the concentrates. A ratio of almost one-half silver to one part of gold by weight is found in the Empire, North Star, and Slate Ledge; still smaller quantities are reported from the Orleans, Osborne Hill, and Maryland, where it sinks to one-third or less that of gold. The concentrates of the Omaha and W. Y. O. D. carry about twice as much silver as gold.

There is not much definite information as to the contents of the separate minerals of the concentrates, but, as stated above, gold may be seen occasionally included in almost any one of them. In some mines the galena appears to be very rich in gold.

In order to ascertain the relative preponderance of metals, several analyses were made by Dr. Hillebrand of representative concentrates. Two analyses by F. Claudet, quoted by J. A. Phillips in his Mining and Metallurgy of Gold and Silver, are here given under I and II.

Analyses of concentrated sulphurets.

	I.	II.	III.	IV.	V.	VI.
Silica	10.97	14.23				
Titanic acid				.590		
Sulphur	46.70	43.72				
Arsenic	.31	1.36	.155	.041	8.950	.006
Tellurium				.026		.008

Analyses of concentrated sulphurets—Continued.

	I.	II.	III.	IV.	V.	VI.
Gold	.04	.03	Not det.	.013	.004	Not det.
Silver	.04	.01	Not det.	.033	.005	.044
Iron	41.65	39.25				
Nickel			.025	.850	.013	.024
Cobalt		.15	(?)	.110		
Chromic oxide				1.620		
Copper	Trace.	0.22	.030	.820	.069	.564
Lead	Trace.	Trace.	.240	1.008	.395	2.730
Zinc			.065	Trace.	.370	1.190
Cadmium					Trace?	.053
Bismuth					Trace?	.008
Tin					Trace?	Trace?
	99.71	98.97				

I. Grass Valley. Analyst, F. Claudet.
II. North Star. Analyst, F. Claudet.
III. North Star. Analyst, W. F. Hillebrand.
IV. Maryland. Analyst, W. F. Hillebrand.
V. Federal Loan. Analyst, W. F. Hillebrand.
VI. Providence. Analyst, W. F. Hillebrand.

Attention is called to the unexpectedly large percentage of tellurium in the Maryland mine. Tellurium was also found in the sulphurets from the Nevada City mine, while those from the Empire and Omaha mines gave negative results. The presence of bismuth, cadmium, and possibly tin is of interest. Chromic oxide is found only in the Maryland mine, occurring on the contact of serpentine and diabase. At the time of this examination there was considerable altered country rock milled containing quartz stringers, and it is not impossible that the Cr_2O_3 may have been derived from that.

THE VALUE OF THE ORES.

High-grade ores are found on the narrow veins of the Banner Hill district, even reaching $50 and $100 per ton, but a good average of the mines working on a large scale would probably be $15 to $20 per ton. In the Nevada City district the average would probably also be $15 per ton, though there are great variations, many of the minor veins containing small but very rich pay shoots. In Grass Valley the average tenor is decidedly higher. Fair statistics are available, from which it is clear that it is in this vicinity $20 per ton. No law can be deduced as to the tenor of the ore in different country rocks. Rich ore shoots appear to occur in all formations.

The value of the free gold obtainable by simple amalgamation is generally much higher than that of the gold in the sulphurets. Rarely, as in the North Banner, does the gold in the sulphurets equal the quantity of free gold.

The value of the gold always greatly exceeds that of the silver; counted by weight, there are only a few mines in which the silver approaches or equals the weight of the gold produced. Among these are many of the Banner Hill and Willow Valley mines. The ratio between gold and silver by weight, though variable in the same mine, is, for instance, 1:1 in the Lecompton, 4:3 in the North Banner, 7:4 or 5 in the Mountaineer. In the Providence and Champion mines it appears to vary from 5:1 to 7:10, the latter being the highest figure for silver recorded.

These figures are derived from the tables of production of the mines in the Mint Reports. It is believed that the assay values would show a somewhat higher percentage of silver, for the reason that in treating argentiferous gold ores a relatively larger quantity of silver is lost in the tailings.

SUPERFICIAL ALTERATION.

The upper part of the vein near the surface is generally decomposed and forms a reddish, crumbling or soft mass of limonite and quartz. The process consists, as is well known, in an oxidation of the sulphides, with accompanying liberation of the gold and a general loosening of the texture. This decomposition extends a variable distance from the surface, very seldom, however, more than 200 feet on the incline of a vein dipping 45° or below a vertical depth of 150 feet. On the other hand, it is common enough, especially in veins with little sulphurets, to find fresh ore almost at the surface. The process is, on the whole, of slight extent and importance compared with other mining districts. In consequence of the liberation of the gold from the sulphurets, the surface ores are easily reduced, and in consequence of the removal of other substances than the gold, they are also generally richer than the fresh ore below. In this process the silver is also partly removed. The decomposed croppings of the Grass Valley veins often contained from $80 to $300 per ton, while the average tenor in depth is from $20 to $30. At present very little of this surface ore remains.

THE STRUCTURE OF THE ORE.

Differing structures.—Four distinct kinds of structure occur in the ores:

1. Massive structure. Massive quartz with sulphurets in wholly irregular distribution. No law can, as a rule, be discovered in the order of deposition of the different sulphurets. This structure is very common.

2. Banded structure by deposition. In this somewhat less common form of structure distinct bands or streaks of sulphurets lie in the generally massive quartz parallel to the walls of the vein. In the Providence shoot of the Ural vein this structure was beautifully shown, and is mentioned from many other places in the detailed descriptions. No definite rule could be made out as to the distribution of the different

sulphides, all frequently occurring mixed in one streak. It has, however, been noted that the chalcopyrite is, often at least, later than the galena and pyrite. The banded structure is illustrated by Pl. VII, fig. *a*, showing Omaha ore with banded pyrite on the left. In smaller veins both of these structures are frequently found with druses and transitions to comb structure. (Pl. VIII, fig. *a*.) Symmetrical deposition of bands on both walls is not often seen, probably on account of the flat dip of the veins. The sulphurets occurring in banded form by deposition are very often shattered by subsequent slight movement. Such a shattering may, to some extent, be seen in the specimen from the Omaha mine (Pl. VII, fig. *a*), but in far more characteristic form in the specimen shown in Pl. VIII, fig. *b*, illustrating ore from the twentieth level of the Empire mine. In this specimen minute specks of gold may be seen plentifully sprinkled in the pyrite and galena.

3. Banded structure by subsequent movement on the vein, or *ribbon structure* proper. This form is extremely common, but has rarely been recognized as due to a sheeting of the vein after its deposition. The explanation generally given for it is that it is due to deposition or to reopening of the vein. The structure is characterized by the branching of the cracks in detail and by the drawn-out streaks of sulphurets noted along the fissures. Gold is frequently found in plates and coatings along these sheets, evidently deposited as a secondary concentration. The microscopical structure gives conclusive evidence as to the crushing of the quartz.

Pls. IX and X show the ribbon structure of the Merrifield vein, Providence mine, stopes between thirteenth and fifteenth levels. The vein is 20 inches wide; 12 inches on the foot wall show massive white quartz with some sulphurets, and with small cavities in which crystal points protrude. The next 5 inches are partly shattered, and a strong sheeting is developed in the last 3 inches next to the hanging wall. Again, the branching character of the cracks and the drawn-out streaks of pyrite and galena are characteristic; no gold is visible with the magnifying glass. Only the upper half of the vein is represented on the photograph.

Finally, the ribbon structure, in contrast to the banded structure, is illustrated in Pl. VII, fig. *a*, from the Omaha mine, fourteenth level. Free gold is seen with the magnifying glass both in the banded pyrite and galena and in the pyrite along the fissures to the right.

4. Banded structure by reopening. A banded structure is sometimes met with which is apparently due to the reopening of the filled vein and the deposition of a new layer. Structures probably due to this have been noted from several places, but they are not always easy of identification as such, for an interruption in the vein-filling process might have produced a very similar result. A good example of this structure is shown in a vein 1½ inches wide from the Osborne Hill mine. The vein is divided in two by a surface covered with small crystals of arsenopyrite, and each part shows independent comb structure.

Microscopic features.—The normal vein quartz has a very characteristic granular, hypidiomorphic structure, which in its essential features remains the same, though the dimensions of the grains may vary greatly. The grains border partly with irregular lines, partly with crystallographic outlines, and the larger grains are penetrated by smaller, more or less perfectly developed quartz crystals. This is illustrated on Pl. IV, figs. *a* and *b*. Miarolitic cavities, in which the points of crystals project, are common, and are filled with calcite or opal. The galena, chalcopyrite, and blende never show crystal form, while cubes of pyrite are frequently seen, and arsenopyrite nearly always appears, with crystallographic outlines.

Other minerals than quartz are rarely present. Calcite occasionally appears, and sericite also, the latter confined to the vicinity of fragments of country rock and never embedded in the massive quartz. Shreds of chlorite occasionally appear in the quartz (Maryland mine). Barite and fluorite do not occur. Feldspars, zoisite, and epidote have not been detected in the vein quartz.

Fluid inclusions are extremely abundant; they are usually small, of irregular form, sometimes have rapidly moving bubbles, and are, as a rule, arranged in different planes in adjoining grains; a dependence on crystallographic planes is sometimes recognized. In other cases the inclusions are continuous across adjacent grains and show a peculiar radiating arrangement dependent on the sulphides in the quartz; long-drawn form or arrangement parallel with the walls of the veins appears only exceptionally. The bubbles tested did not disappear on heating to + 30° C., and it is not probable that they contain carbonic dioxide.

No recognizable relation exists between the fluid inclusions and the richness of the quartz.[1]

During the earlier investigations of Davy, Sorby, Brewster, and Vogelsang[2] a great many specimens of vein quartz, with large fluid inclusions, from Schemnitz, Hungary, Guanaxuato, Mexico, and other localities, were tested, and the results showed that the contents were chiefly solutions of chlorides and sulphates in water.

A large quantity of clean quartz with but little pyrite from the Merrifield vein, Providence mine, fifteenth level, was examined for soluble salts by Mr. George Steiger. Five hundred grams of the powdered rock was treated with cold water for two days; then heated three hours on the water bath and filtered. This gave a milky filtrate which amounted to about 1,000 c. c. The filtrate was evaporated to 50 c. c. and filtered again. This filtrate was perfectly clear, and its analysis is marked B. The residue on the filter was examined separately, its analysis being marked A. This residue contained some carbonates which had evidently been in solution.

[1] Cf. W. M. Courtis, Trans. Am. Inst. Min. Eng., Vol. XVIII, 1889, p. 639.
[2] Rosenbusch, Physiographie der Mineralien.

[Grams per ton of quartz.]

	A.	B.
SiO_2	3	28
Al_2O_3, Fe_2O_3	2	2
CaO	13	44
MgO		1
$(KNa)_2O$		29
SO_3		78
Cl		5
	18	187

The result shows the presence of sulphates of calcium and alkaline sulphates, together with very little chloride. The sulphuric acid could not have been derived from the pyrite, for there is scarcely any iron present. In all probability the soluble salts were contained in the fluid inclusions. Some silica, probably amorphous, has also been dissolved, as well as a little carbonate.

The occurrence of carbonic acid has been shown by Dr. Hensoldt in a specimen of quartz from the Tiger mine, Calaveras County.[1]

It is extremely common to find the vein quartz broken and crushed along certain lines, and the appearance of this crushed quartz under the microscope is identical with the effects of crushing, so often described, in massive granular rocks. An excellent example of this structure is shown on Pl. VI, fig. *a*. The crossed nicols bring out the slight difference in the optic orientation of the crushed parts of each grain. Actual faulting has taken place, and along the fault lines a crushed aggregate of new, ragged, and irregular quartz grains is formed. If this process is carried somewhat farther a sheeting of the vein will result, and along the planes broad streaks of secondary quartz aggregates will be formed. New slight fissures are sometimes formed, and by a process of secondary concentration gold and sulphides may be deposited along these planes. To this the frequent richness of the ribbon quartz is no doubt due. The masses of sulphides in the way of the fractures are broken and pressed out in long streaks. Pl. VI, fig. *b*, shows the structure of the quartz from the large specimen of ribbon quartz illustrated by Pl. IX. The section is made from the quartz next to the wall, and shows well the contrast between the fresher quartz and sulphurets preserved on the left and the finer aggregate structure of the quartz and pressed form of the pyrite on the right. The partings in the ribbon quartz may often show a parallel striation. Under the microscope the ribbon structure by sheeting is distinguished from that by reopening or deposition by the fact that in the latter there is no indication of pressure in the quartz, or at least only on one side of the dividing plane, while the quartz on the other side is deposited as a mold on the parting plane without showing any dynamic disturbance.

[1] Paper by W. M. Courtis quoted above.

PLATE VI.

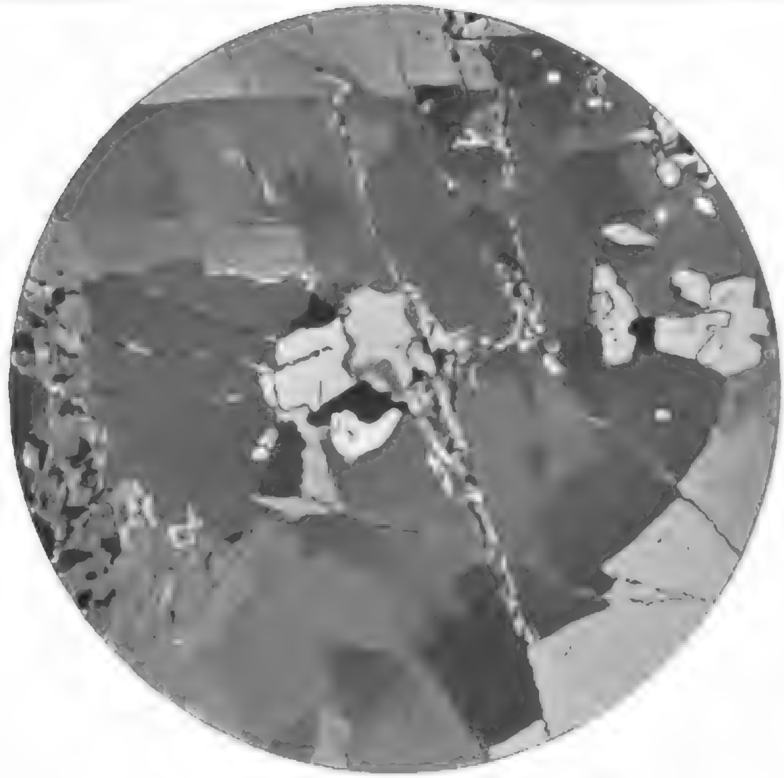
THIN SECTIONS SHOWING STRUCTURE OF ORE.

FIG. *a*. Crushed vein quartz and incipient ribbon-structure; Nevada City mine; 134 N. C.

Magnified 15 diameters.
Crossed nicols.
Only quartz.

FIG. *b*. Ribbon-structure, showing crushed quartz and pressed pyrite. Original aggregates of quartz and pyrite to the left. From specimen shown in Pls. IX and X.

Magnified 17 diameters.
Crossed nicols.
Black areas, pyrite.
All other areas, quartz.



a

b

THIN SECTIONS, SHOWING STRUCTURE OF ORE.

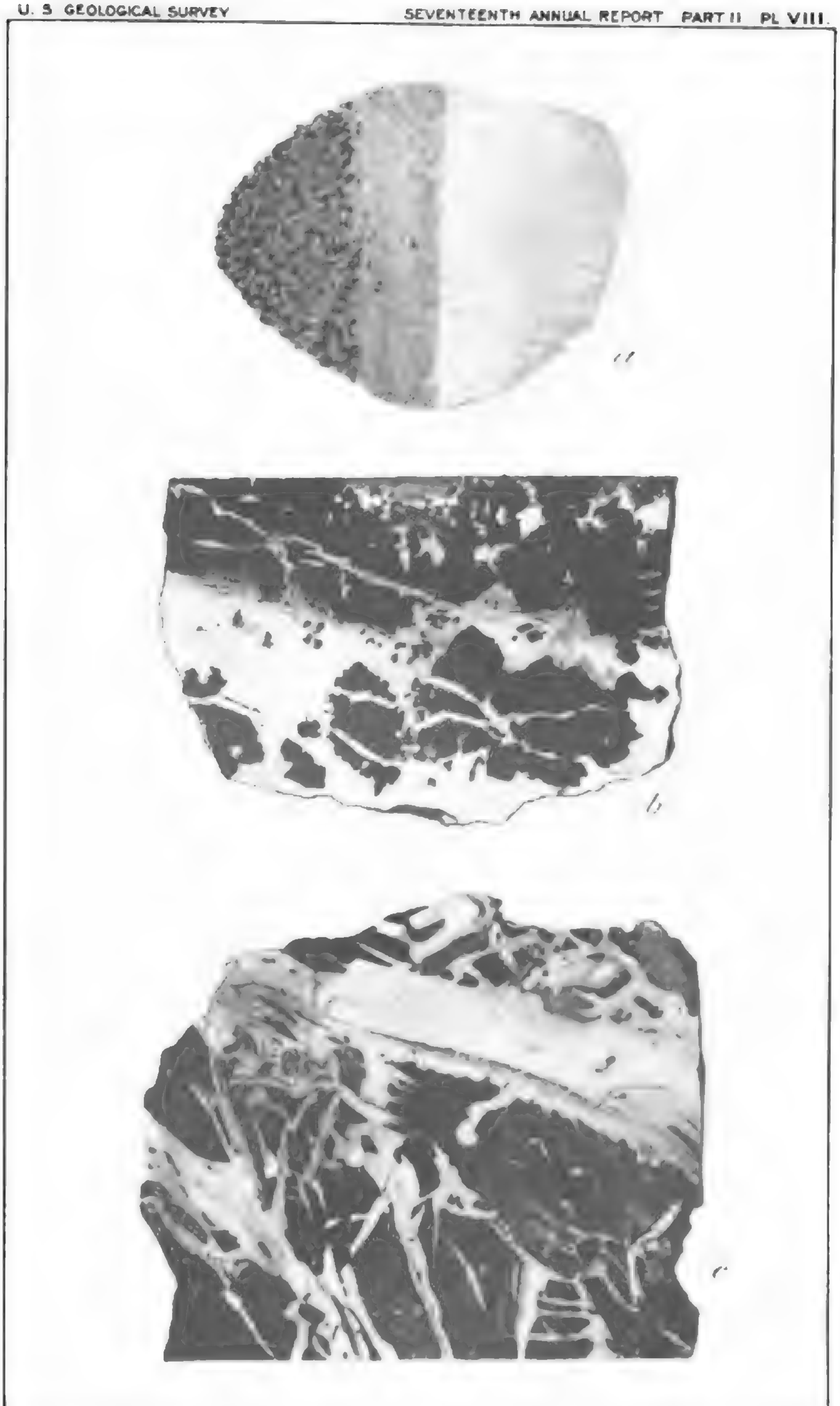
PLATE VIII.

SPECIMENS SHOWING STRUCTURE OF ORE.

FIG. *a*. Thin section of 2-inch quartz seam in diorite; California mine, Dead Mans Flat; 143 G. V. Quartz shows comb-structure. The wall rock a basic diorite with pyrrhotite, altering next to vein to calcite, sericite, and pyrite.
Natural size.

FIG. *b*. Vein quartz; Empire mine, twentieth level; 155 G. V. Showing crushing of pyrite and galena, and recementing by later quartz seams.
Natural size.

FIG. *c*. Vein quartz; Banner mine. Showing shattering of black argillite by quartz seams; pyrite developing in the argillite, but not in the quartz; further, brownish (weathered) carbonates deposited next to the argillite in the seams. Beginning of metasomatic alteration apparent by bleaching of the black argillite.
Natural size.



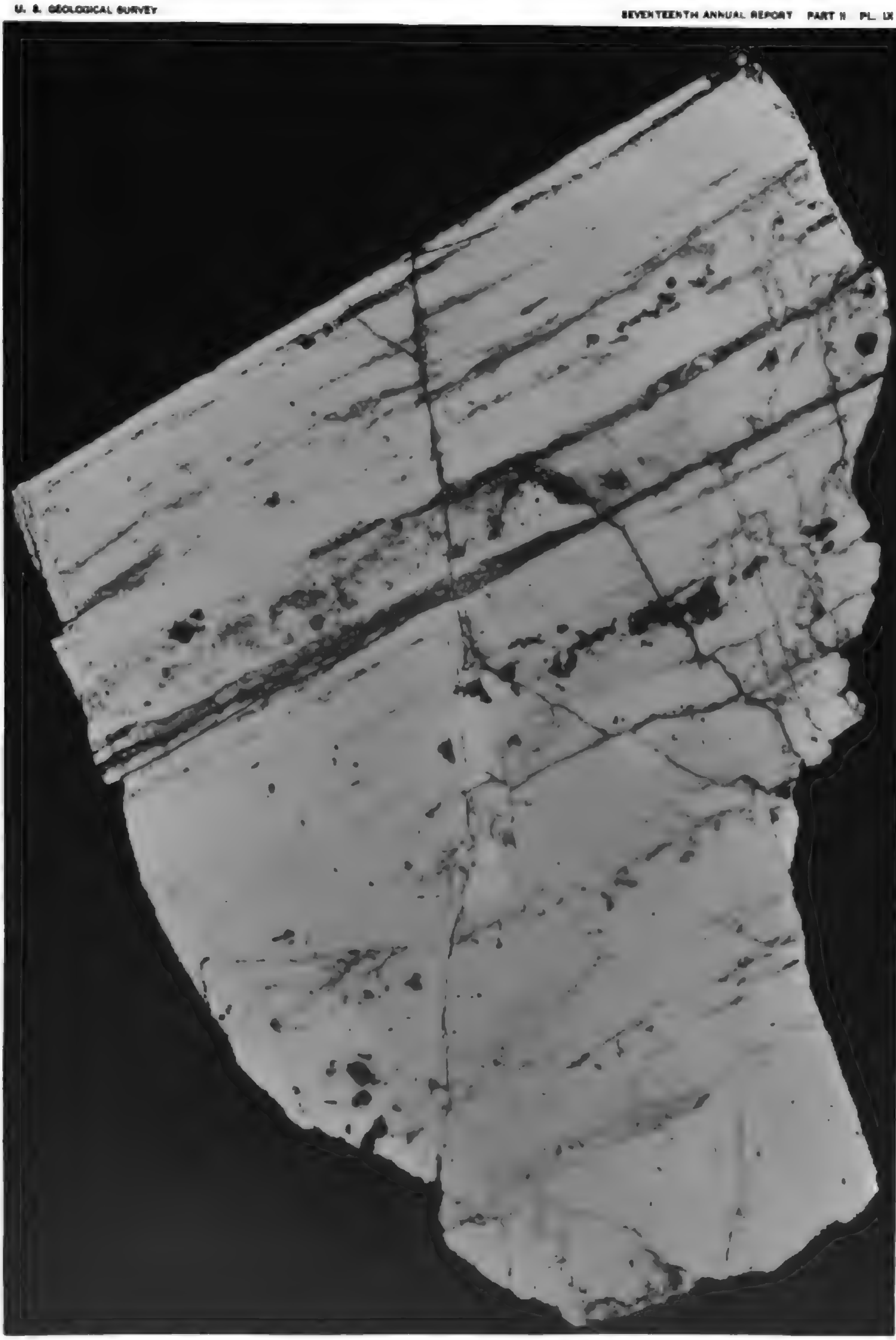
SPECIMENS SHOWING STRUCTURE OF ORE. NAT. SIZE.

PLATE IX.

VEIN QUARTZ, MERRIFIELD VEIN.

Vein quartz; Merrifield vein, Providence mine, fifteenth level, south. Vein 2 feet wide; only one-half of it, adjoining hanging wall, is represented. Lower half massive quartz; upper half showing typical ribbon-structure by sheeting subsequent to deposition. Showing branching fissures and pressed pyrite.

Two-thirds of natural size.



SPECIMEN FROM MERRIFIELD VEIN, SHOWING STRUCTURE OF ORE.

PLATE X.

VEIN QUARTZ, MERRIFIELD VEIN.

Specimen from Merrifield vein, fifteenth level, south; showing typical ribbon-structure with branching fissures and pressed pyrites.

SPECIMEN FROM MERRIFIELD VEIN, SHOWING STRUCTURE OF ORE.

Natural size.

CHAPTER X.

CHANGES IN THE ROCKS DUE TO FISSURE AND VEIN FORMATION.

GENERAL FEATURES.

Along the veins the rocks show notable mechanical and chemical changes. The first is shown by lines of fracture and by breccias, cemented by quartz. It is also, but more rarely, shown by wide-reaching mechanical deformation of the rock, producing schistose and slaty structure. The character of the fissures as integral parts of extensive sheeting and jointing implies less of a long-continued and intense movement on the shearing planes, and more of a sudden break or crush, with the formation of a single fissure or of breccias and branching veinlets. The chemical change is of uniform character, and is always present, but may be more or less emphasized; its universal occurrence and the mineralogical character of the process point unmistakably to a chemical reaction and interchange of substance between the rock and some fluid once filling the fissures. In other words, it is a process of substitution or metasomatic replacement.

MECHANICAL ALTERATION.

The breaking and brecciating of the rocks along the fissures have not, as a rule, produced an extensive mechanical alteration, though in coarse-grained rocks the constituents are often, under the microscope, seen to be somewhat crushed, and the quartz grains often acquire undulous extinction. More rarely appears a schistosity of the rock next to the vein, produced by the shearing force exercised in breaking the fissure, and also by the grinding of the walls against each other after the break.

It is only along the Merrifield and Ural veins, on which, as shown in the detailed descriptions, extensive faulting has taken place, that this schistose structure is developed on a large scale. This is especially well seen in the Champion, Providence, and Nevada City mines. The zone in which the schistosity is developed is from a few feet up to 20 feet wide, and in it one or several quartz veins may be contained, as explained. The granodiorite is converted to a greenish-gray rock, breaking in flat irregular fragments, bounded by smooth greenish faces with greasy feel. The planes of schistosity are curved, and the structure is produced irregularly, less altered masses alternating with thoroughly schistose streaks. The chemical alteration of these rocks is

intense, and will be discussed later. The mechanical deformation is equally pronounced. The quartz grains are completely shattered; the whole coarse aggregate of the granodiorite is crushed to a greenish, fine-grained, allotriomorphic aggregate, often with a somewhat splintery fracture, drawn out in long streaks and stringers. The carbonaceous schist of the Ural foot wall is equally crushed, though the effect on the individual grains is here not visible, owing to the original fineness of grain. The resulting mass is a black, soft rock with irregular and curved black and shining planes of schistosity, much more irregular, in fact, than the original planes of schistosity of the rock.

CHEMICAL ALTERATION.

GENERAL FEATURES.

The chemical alteration which the rock next to the quartz has undergone is developed with very different intensity. In some mines, indeed, like the Mountaineer and Omaha, sometimes also in the Empire and North Star, comparatively fresh rock lies close up to the vein, while in others the zone of alteration may be several feet wide. The most extensively altered rock is usually the brecciated mass lying between two closely approaching fractures or walls. The resulting rocks, often entirely different in appearance from the fresh rock, usually have a yellowish-gray to gray or white appearance, and frequently a greasy feel. It is easy to find all kinds of transitions, from the incipient to the most advanced alteration. All rocks are subject to this alteration, even the siliceous argillite from the Federal Loan; in carbonaceous fissile argillites, however, such as in the Merrimac mine, the alteration is very slow and chiefly confined to the introduction of pyrite. All minerals are subject to it, even the quartz of the granodiorites.

MINERALOGICAL CHARACTER OF ALTERATION.

The changes in the rocks are chiefly due to the formation of three classes of minerals: (1) *Carbonates*, chiefly calcite, pure, or more frequently with a small admixture of the carbonates of iron and magnesium, the former producing a brownish color in weathered fragments. Near veins in serpentine the magnesium carbonate prevails. (2) *Potassium micas*, usually in fine-felted aggregates of wavy fibers, with often silky luster; the name sericite has been used for these micaceous aggregates, according to precedent, although it is probable that the composition varies little if any from that of normal muscovite. It is hardly ever possible to obtain the mineral in a sufficiently pure state for analysis. Other potassium micas occurring connected with altered wall rocks are the so-called mariposite (cf. p. 115), which is colored green by chromium and is probably identical with fuchsite. A vanadium mica, roscoelite, also occurs on veins in Eldorado County. (3) *Sulphides*; pyrite is extremely abundant in sharp, cubical crystals, and

in some mines arsenopyrite also appears in idiomorphic forms. Calcite or quartz rims often surround the cubes of pyrite.[1] No other sulphides have been observed. Pyrrhotite, which is extremely common as a result of metamorphic processes in certain rocks of the district, is not found in the altered wall rock. Abundant examples show that it is transformed into pyrite when within the influence of the fluids circulating on the fissures.

Besides these principal groups of minerals others may occur. Small quantities of chlorite have been observed, but the process is on the whole not favorable to the development of this mineral; titanite (leucoxene) is frequently present, due to an alteration from ilmenite or titaniferous magnetite; chromite has been observed; magnetite is absent, and seems to have been converted into ferrous carbonate or perhaps also into pyrite.

This process is one of metasomatic interchange—that is, "an interchange of substance without necessarily involving, as does pseudomorphism, the preservation of the original form of the substance replaced, or even of its original volume."[2]

Metasomatic interchange or replacement, in a restricted sense, necessitates chemical action between the mineral attacked and the solvent; of such character are, nearly exclusively, the processes here described. In a wider sense, it also includes processes by which the original mineral is dissolved as a whole and a new substance deposited in its stead without chemical action between the two substances, as, for instance, in the case of quartz replacing calcite.

Replacement by silica is not among the processes here recognized. It should be borne in mind that a rock shattered and filled with quartz seams is not an evidence of metasomatic replacement by quartz, nor is such a rock a quartz vein in process of formation. In a mineral water containing carbon dioxide, sulphureted hydrogen, carbonates, and silica, the former three compounds will vigorously attack, by chemical processes, the minerals of any ordinary rock, and form new compounds, while the silica is inert and plays a passive rôle. It has not been noted that the silica in the mineral waters forming the vein has replaced any of the rock minerals. Most of the silica set free by the process of carbonatization has probably been removed and deposited in the fissures, while some of it—especially where thermal waters permeate whole rock masses and no free ducts exist—may be deposited in the altered rock as secondary aggregates. If a silicification of the wall rocks is found at any place in the California gold-quartz veins, it will probably be in easily soluble rocks, such as limestone.

It is necessary to separate strictly the quartz filling in the veins deposited in open spaces from the metasomatic country rock. The

[1] The ease with which large idiomorphic crystals of pyrite may develop in certain rocks, such as the chloritic diabase of the Idaho and the Kentucky mines, is very remarkable as showing the intensity of the metasomatic process.

[2] Emmons, Mon. U. S. Geol. Survey, Vol. XII, p. 565.

latter, however altered, bears evidence of its metasomatic character, while the former, in its structure, clearly indicates a crystallization in open space.

In the ordinary course of the metasomatic process, as here shown, augite, hornblende, uralite, feldspar, and epidote are first vigorously attacked. Proceeding along cracks in the minerals, a finely felted calcite and sericite aggregate invades the grains until the replacement is complete. The hornblende is sometimes converted directly into coarse foils of muscovite, and in the feldspar grains there is often, also, a distinct tendency of the sericite fibers to parallel arrangement, finally resulting in the forming of large foils. An interlacing structure of mica foils with the interstices filled with calcite is sometimes met with (Federal Loan). The quartz is also attacked, but with more difficulty than the other minerals; from many localities there is unequivocal evidence of a process of replacement gradually eating away the quartz. In fig. *b* of Pl. V the resulting aggregate is chiefly composed of calcite with a little sericite. In other slides the product is chiefly sericite. The relative preponderance of the carbonates and the mica is subject to variation in the same mine. As the examples below indicate, they usually occur together, but occasionally (analysis from the Idaho) the carbonates may entirely prevail, or (analysis from the Osborne Hill) the rock may be almost entirely composed of sericite. The quantity of pyrite is usually large, and it appears as if the pyrite were derived mostly, not from the magnetite, but from the ferrous silicates.

In addition to the metasomatic alteration, the rock is very commonly traversed by small fissures, which generally are filled with carbonates or a mixture of carbonates and quartz, more rarely with quartz alone. This characteristic is often very prominent, and it seems at first glance strange to see the quartz vein adjoined by a rock traversed in all directions by veinlets of carbonates.

SUBSTANCES LOST OR INTRODUCED.

The chief and marked characteristics of the altered wall rock are the introduction of carbon dioxide, sulphur, and potassium; the latter is especially emphasized, because the prevailing rocks of the districts are decidedly richer in sodium than potassium, and the conclusion is unavoidable that not only has the sodium been leached out but potassium actually introduced in the rock. Analysis I of the altered wall rocks is especially instructive compared with the analyses of fresh granodiorites.

The percentage of silica is lowered by at least 10 per cent; the aluminum appears fairly constant, as does the iron, though part of it is converted into sulphides. The calcium in some cases remains constant, while it is considerably increased in most rocks; the magnesium is not much changed. Sodium has been extensively removed. Titanic acid remains constant, as does the phosphoric acid of the apatite.

In some analyses the presence of barium in not greatly differing quantities from that of the fresh rock is of interest. Water, above 110° C, is present in pretty constant quantity, ranging from 1 to 3 per cent; extensive hydration has certainly not taken place, and in the case of altered serpentines there is a distinct dehydration.

Analyses of altered wall rocks.

	I.	II.	III.	IV.	V.	VI.	VII.	VIII.
SiO_2	56.25	60.26	59.76	34.91	36.19	45.74	58.43	71.97
TiO_2	.25	.42	.46	1.65	.16	.36	None.	.88
Al_2O_3	17.65	15.73	14.45	15.55	4.93	5.29	17.40	15.75
Fe_2O_3	.76	1.25	1.01	.17	.21	.13	.77	.77
FeO	*a* 2.64	2.68	3.52	*a* 4.96	5.36	2.06	*a* 2.19	*a* .45
FeS_2	2.87	.08	.24	4.20	.22	.49	1.59	.56
MnO	None.	.04	.09	None.	.12	.26	None.	None.
NiO	......	......	......	......	*b* .10	......	......	......
CaO	4.46	5.44	6.09	11.10	4.60	23.85	5.25	.80
SrO	......	Trace.	Trace?	......	Trace.	None.	......	......
BaO	.03	.07	.05	None.	Trace.	Trace.	None.	Trace.
MgO	1.69	1.82	2.26	4.58	22.94	*c* .94	1.50	.80
K_2O	6.01	3.71	3.73	4.28	.06	1.29	4.03	4.88
Na_2O	.30	1.92	1.12	.19	.16	.11	1.76	.33
Li_2O	......	Trace.	Trace.	......	Trace.	Trace.	......	......
H_2O below 110° C	.30	.33	.26	.30	.18	.22	.30	.30
H_2O above 110° C	2.36	2.54	2.58	1.86	2.87	1.07	2.61	2.16
P_2O_5	.21	.12	.16	.82	.05	.07	.13	.15
CO_2	4.82	3.99	4.47	15.57	21.82	18.91	4.04	.38
SO_3	None.	......	......	None.	......	......	None.	Trace.
	100.60	100.40	100.28	100.14	99.97	100.79	100.00	100.18

I. Bellefountain tunnel (42 N. C.), derived from granodiorite. Analyst, George Steiger.
II. Providence mine, front vein (208 N. C.), derived from granodiorite. Analyst, W. F. Hillebrand.
III. Providence mine, back vein (212 N. C.), derived from granodiorite and schist. Analyst, W. F. Hillebrand.
IV. Federal Loan mine (38 N. C.). Analyst, George Steiger.
V. Idaho, 10th level (148 G. V.), derived from serpentine. Analyst, W. F. Hillebrand.
VI. North Star mine (104 G. V.), derived from uralite diabase. Analyst, W. F. Hillebrand.
VII. Empire mine (151 G. V.), derived from granodiorite. Analyst, George Steiger.
VIII. Osborne Hill mine (83 G. V.), derived from fine-grained sandstone. Analyst, George Steiger.

a These determinations of FeO were unsatisfactory on account of FeS_2.
b Nickel not looked for elsewhere, but certainly not present in more than traces.
c Approximate.

For comparison the following analyses of fresh rocks are appended:

Analyses of unaltered rocks.

	I.	II.	III.
SiO_2	66.65	51.01	73.63
TiO_2	.38	.98	.52
Al_2O_3	16.15	11.89	10.54
Fe_2O_3	1.52	*a* 1.57	*b* 1.87
FeO	2.36	*a* 6.08	
MnO	.10	Trace.	Trace?
Cr_2O_3		.04	
CaO	4.53	10.36	2.47
CuS		Trace.	
SrO	Trace.		Trace.
BaO	.07	None.	.12
MgO	1.74	8.87	1.84
K_2O	2.65	.15	1.89
Na_2O	3.40	4.17	1.81
Li_2O	Trace.		Trace.
H_2O below 110° C	.18	.24	.11
H_2O above 110° C	.72	2.09	1.07
P_2O_5	.10	.17	.13
CO_2			.62
FeS_2	.02	1.73	
Fe_7S_8?			3.16
Carbon of organic matter			.59
	100.57	99.35	100.37

I. Granodiorite, Shurtleff's barn, Nevada City. Analyst, W. F. Hillebrand.
II. Diabase, 600 feet south-southeast of Maryland shaft (121 G. V.). Analyst, H. N. Stokes.
III. Siliceous argillite somewhat contact-metamorphosed, Federal Loan (38 N. C.). Analyst, W. F. Hillebrand.

a Fe_2O_3 and FeO are approximate only because of presence of sulphides.
b Because of the organic matter and soluble sulphide the FeO could not be estimated. Therefore all iron after deduction of that needed for Fe_7S_8 is counted as FeO. The FeO given in other analyses where there is much pyrite is perhaps only near the truth. Any error in such cases of course affects the Fe_2O_3 in an opposite direction.

On the whole, the analyses show a relatively small amount of leaching of any substance except silica and sodium: large quantities of the latter especially have been removed.

EXAMPLES OF ALTERED GRANODIORITE.

A specimen from the Bellefountain tunnel, Banner Hill tract, is of a yellowish-gray mottled color and granular structure, made evident by quartz grains and darker spots representing remains of hornblende. Sharp, cubical crystals of pyrite abound. Under the microscope the

granitic structure is very clear. The hornblende and mica are converted into large muscovite foils. The black iron ores are converted into milky opaque substances. The feldspars are completely changed into a fine-grained sericitic aggregate, often showing approximately parallel arrangement of the fibers, or, also, two systems of fibers at right angles. Smaller masses of calcite lie between the sericite fibers. Sharp cubes of pyrite lie in the aggregate, containing included masses of the micaceous mineral. There is practically no feldspar left, while many of the quartz grains have retained their original form. In other grains the sericite is undoubtedly corroding the quartz grains in exactly the same manner as shown from the specimen 111 N. C. on Pl. V, fig. *b*.

Analysis I in the table shows the composition of this typical rock. Estimating that there is 25 per cent of unaltered quartz in the rock, the constituents may be calculated as follows:

	Per cent.
Calcium carbonate	7.23
Magnesium carbonate	2.70
Iron carbonate	.58
Pyrite	2.87
Apatite	.46
Titanite	.60
Quartz	25.00
Sericite	61.11
	100.55

The composition of the sericite may be calculated as follows:

	Per cent.
SiO_2	51.09
Al_2O_3	28.87
Fe_2O_3	1.25
FeO	3.85
MgO	.66
BaO	.05
K_2O	9.83
Na_2O	.50
H_2O	3.90
	100.00

This corresponds fairly well to an acid muscovite, except that the FeO is too high; this may be explained by the uncertainty of its determination in the presence of so much FeS_2.

The crushed and schistose granodiorite from "New Shaft" on the Merrifield vein, Providence mine (111 N. C.), is a grayish-green mottled rock with curved planes of schistosity and greasy feel. It effervesces strongly with hydrochloric acid. The feldspars and hornblende are entirely converted to micaceous aggregates, with irregular patches and veinlets of calcite. Much of the quartz remains, but is nearly everywhere, in the process of conversion to calcite, mixed with a little sericite. The quartz is greatly crushed and drawn out to lenticular aggregates. A portion of this slide is illustrated in Pl. V, fig. *b*; the quartz is somewhat crushed, but is still plainly seen to be composed of only one or two original grains. The small calcite grains forming abundantly along or near the cracks in the fresh quartz are very characteristic, and the whole is unquestionably a process of metasomatic replacement.

In a fissured quartz grain the individual cracks might be filled with calcite, and thus the appearance of metasomatic replacement created. The criterion of the replacement is the inward progression of the new aggregates, resulting in irregular and ragged masses, and the fact that the separated portions of the quartz no longer fit together.

Specimens from the Merrifield vein in Providence mine, thirteenth level, show the same greenish-gray mottled and schistose rock, sometimes almost serpentinoid in appearance; in places granitic structure is still visible. Small seams of quartz and calcite traverse the rock, and sharply defined cubes of pyrite lie embedded in it. Under the microscope the rock is very similar to the one just described; the quartz is in places drawn out to long strings of aggregates; calcite seams surround the pyrite; the feldspar is largely converted to sericite with calcite. A little chlorite is also present. The analysis of this rock is shown under II, p. 149. It is essentially similiar to I, except that the alteration has scarcely proceeded so far, as is evidenced by the greater percentage of MgO, not needed for carbonates and belonging to the chlorite, and also by the larger remaining percentage of sodium.

The altered granodiorite from the Empire mine, twentieth level, occurring close up to the quartz (151 G. V.), presents the same appearance and effervesces greatly with acid.

The microscopic character is practically identical with the specimen already described, and Analysis VII shows that the composition is also practically identical. Many small veins of quartz cut the sericitic aggregates.

EXAMPLES OF ALTERED DIABASE.

A specimen of the altered porphyritic uralite-diabase from the hanging wall of the North Star vein, twentieth level (10 G. V.), is a grayish-green rock with fine-grained groundmass and small greenish feldspar crystals. Under the microscope the rock is shown to be far more altered than its appearance would indicate; the diabasic structure of feldspar grains, in part interlocking, in part lath-like, is still visible but greatly obscured by an all-pervading aggregate of sericite, calcite,

and chlorite. Grains of titanic iron ore or titaniferous magnetite are in process of alteration to a bluish-white substance, probably titanite.

The partly crushed rock between the walls of the vein is greenish-gray, soft and dense, and is traversed by narrow veinlets of carbonate, quartz, and pyrite. The alteration has here gone further and the original structure is scarcely recognizable. The analysis of this rock is given under VI, from which it is apparent that a great quantity of calcite is present. The analysis may be roughly calculated as follows:

	Per cent.
Calcite	42.15
Magnesite	.71
Pyrite	.50
Quartz	35.00
Titanite	.85
Sericite (with chlorite)	20.79
	100.00

The sericite is not pure, as is evidenced by the strong percentage of MgO and FeO. The latter is very high, and it is not certain to which mineral it properly belongs.

The diabase of the hanging wall of the Idaho-Maryland mine is not altered to such an extensive degree as the size of the vein would lead one to suppose. It is a soft, green, chloritic rock, containing only relatively small amounts of carbonates and sericite, but there is much iron pyrites in sharp crystals up to several millimeters in diameter. The microscope reveals a fairly well preserved diabasic granular structure, veiled by films and masses of chlorite; the titanic iron ore is converted to milky opaque aggregates.

EXAMPLE OF ALTERED SERPENTINE.

The serpentine of the foot wall of the Idaho-Maryland vein is, in places, greatly altered. Specimens (147 G. V.) from the sixteenth level near the shaft show near the vein a grayish green, distinctly schistose rock, soft and with greasy feel. At first glance it has the appearance of a little-altered serpentine. Under the microscope it is, however, shown to consist predominantly of carbonates in coarsely granular aggregates between which lies an intimate mixture of chloritic, serpentinoid, and sericitic fibers. Grains of chromite, translucent with deep-brown color, do not appear to have been altered. At the same locality a large mass of the country rock (148 G.V.) is included in the quartz, and this shows a still farther reaching alteration. It is greenish-gray and distinctly schistose; remaining films and streaks of greenish serpentine or chlorite appear in a predominant gray, finely granular mass. Under the microscope the principal constituent is seen to be magnesite in large

grains; there is a little chromite, and many veinlets of quartz. Between the carbonate grains and extending into them lie wavy parallel streaks of a pale-greenish mineral, in part chlorite, in part serpentine. A few grains of pyrite, but almost no sericite, are noted. There are also in intimate connection with the serpentine fine-grained aggregates of quartz. The analysis of this specimen is recorded under V in the table, p. 149. It may be calculated as follows, under the supposition that all of the calcium and the larger portion of the magnesium are present as carbonates, and that there is about 26 per cent free silica present:

	Per cent.
Magnesium carbonate	34.78
Calcium carbonate	8.22
Quartz	26.00
Serpentine, chlorite, and accessories	31.00
	100.00

The residue of serpentine, etc., would then have the following composition:

	Per cent.
SiO_2	34.23
Al_2O_3	16.56
FeO	18.00
MgO	21.57
H_2O	9.64
	100.00

This is evidently a mixture of minerals, probably chiefly chlorite and serpentine. As in the other analyses, the ferrous oxide is in excess, and it is doubtful to which mineral it belongs. The chromium in the rock has not been determined. The free quartz in the analysis results partly from the small veins intersecting the rock, but some of it represents without doubt the silica liberated by the conversion of the magnesian silicates into magnesite.

EXAMPLE OF ALTERED SEDIMENTARY ROCKS.

The massive siliceous argillite from the Federal Loan, of which an analysis is appended on a preceding page, shows under the microscope a very fine grained allotriomorphic aggregate of quartz, feldspar, and brown mica, together with much pyrrhotite and some organic matter. Under the metasomatic influence of the vein solutions this is altered to a yellowish-gray aggregate of sericite, calcite, and residuary quartz; the pyrrhotite is changed to pyrite. This alteration is, in a general way, well shown on Pl. VII, fig. *b*, representing in natural size a piece of

vein quartz adjoining the wall in the Federal Loan mine. Next to the wall there will be observed a large number of small angular fragments of thoroughly altered rock of yellowish-gray color. This zone next to the wall represents the fine detritus accumulated on the foot wall and cemented by quartz. In the main quartz mass are several fragments of country rock in different degrees of alteration. The sharp outlines of the fragments, especially of the one in the lower right-hand corner, show that change in form or rounding of corners does not necessarily accompany the metasomatic process. In most of the fragments is also shown in all degrees a tendency toward replacement by arsenopyrite as a last step in the metasomatic process, as well as an inclination of the pyrite to crystallize around the fragments. The pieces of country rock, it is held, fell into the forming quartz mass simultaneously with its deposition. To some extent this bleaching of the black argillite is also shown on Pl. VIII, fig. *c*. The microscope shows this altered yellowish-gray rock to consist of a mottled mass of clear sericite fibers, between which lie clouded masses of fine grained calcite and some leucoxene (titanite). There are, further, abundant grains of pyrite and some arsenopyrite; in some places there are, with the pyrite, smaller masses of pyrrhotite, very strongly suggesting an alteration of the latter into the former. Many veinlets of carbonates are present, which as a rule contain little pyrite.

An analysis of an altered wall rock collected on the dump of the mine is recorded under IV in the table, p. 149. The rock analyzed is gray, with splintery fracture, contains many small veins of carbonates, as well as much pyrite; small grains of pyrrhotite are occasionally visible. The analysis, while characteristic of the metasomatic rocks of the gold veins, does not indicate a derivation from an argillite, but of a basic rock rich in titanium and magnesium, such as one of the numerous dikes contained at this vicinity in the prevailing rock.

The analysis may be calculated as follows, on the supposition that there is 7.75 per cent free silica present:

	Per cent.
Calcium carbonate	15.82
Magnesium carbonate	9.62
Iron carbonate	8.03
Pyrite	4.20
Quartz	7.75
Titanite	4.14
Apatite	1.82
Sericite	47.79
Water below 110° C	.30
Fe_2O_3	.17
	99.64

In this analysis there is enough carbon dioxide to form carbonates with all of the calcium, magnesium, and iron present. The sericite would, on the above supposition, have the following composition:

	Per cent
SiO_2	54.21
Al_2O_3	32.54
K_2O	8.96
Na_2O	.40
H_2O	3.89
	100.00

Pl. VIII, fig. *c*, represents in natural size a specimen from the old Banner mine (77 N. C.), showing well the shattering of the dark argillite by a network of quartz veins. Having been exposed to weathering, the carbonates containing iron have assumed a brownish color, which permits one to distinguish their frequent deposition along the sides of the veinlets, in contact with the argillite, instead of being mixed irregularly with the quartz. The argillite does not appear much bleached, but is filled by pyrite crystals, while there is no pyrite in the quartz. In thin section this lining of the fragments by calcite is even more characteristic, while the argillite is seen to be more altered in places than would be expected. Sericite fibers have developed in it, and small microscopic veinlets of calcite cut across it.

At the Osborne Hill mine the vein lies in porphyrite breccia, with abundant fragments of a sedimentary, brownish gray, fine grained rock. A specimen of the altered rock adjacent to the vein (83 G. V.) has light gray color, is traversed by many small quartz seams, and contains sharp crystals of pyrite. The thin section shows an original extremely fine grained, clastic structure, chiefly of quartz grains, strongly recalling the argillite of Federal Loan; between the grains, and also in them, lie very fine felted aggregates of sericite fibers. The analysis confirms the microscopic evidence that the rock is derived from a siliceous argillite. The absence of carbonates in the altered rock is notable. The analysis No. VIII in the table, p. 149, may be calculated as follows, on the estimation of 50 per cent free silica:

	Per cent
Quartz	50.00
Sericite	46.24
Calcite	.26
Magnesite	.47
Pyrite	.56
Apatite	.34
Titanite	2.20
Water below 110° C	.30
	100.37

And the sericite would have the following composition:

	Per cent.
SiO_2	46.07
Al_2O_3	34.07
Fe_2O_3	1.67
FeO	.97
MgO	1.30
K_2O	10.55
Na_2O	.71
H_2O	4.66
	100.00

Analysis III shows the composition of the crushed rock from the foot wall of the Ural vein in the Providence mine. It is a dark-gray, fine-grained rock with black, shining, and curved planes of schistosity and containing many small but extremely sharp crystals of pyrite. Under the microscope it is very different from the crushed granodiorite of the hanging wall of the same vein, the original structure being that of an allotriomorphic, fine-grained quartz-feldspar aggregate; this structure is now partly veiled by a development of sericite, carbonates, and chlorite. Besides these are many small crystals of an opaque mineral which may be magnetite. The analysis shows a great similarity to II, which is the crushed granodiorite from the Merrifield vein. The original material is, however, very different.

GOLD AND SILVER CONTENTS OF THE ALTERED WALL ROCKS.

As has been stated before, the wall rocks, replaced by carbonates, sericite, and sulphides, generally contain very little of the precious metals, even when adjoining rich ore shoots. A number of altered rocks were tested by Mr. C. Whitehead, assayer of the mint, with generally negative results.

	Gold.	Silver.
	Per cent.	*Per cent.*
208 N. C., Providence mine (Analysis II)	None.	0.02
212 N. C., Providence mine (Analysis III)	None.	None.
148 G. V., Idaho mine (Analysis V)	None.	None.
22 G. V., Hermosa mine	None.	.30
104 G. V., North Star mine; near rich quartz	Trace.	.20
151 G. V., Empire mine (Analysis VII); near rich quartz	None.	.05

It is worthy of note that the silver predominates, while in the quartz the contrary is the rule.

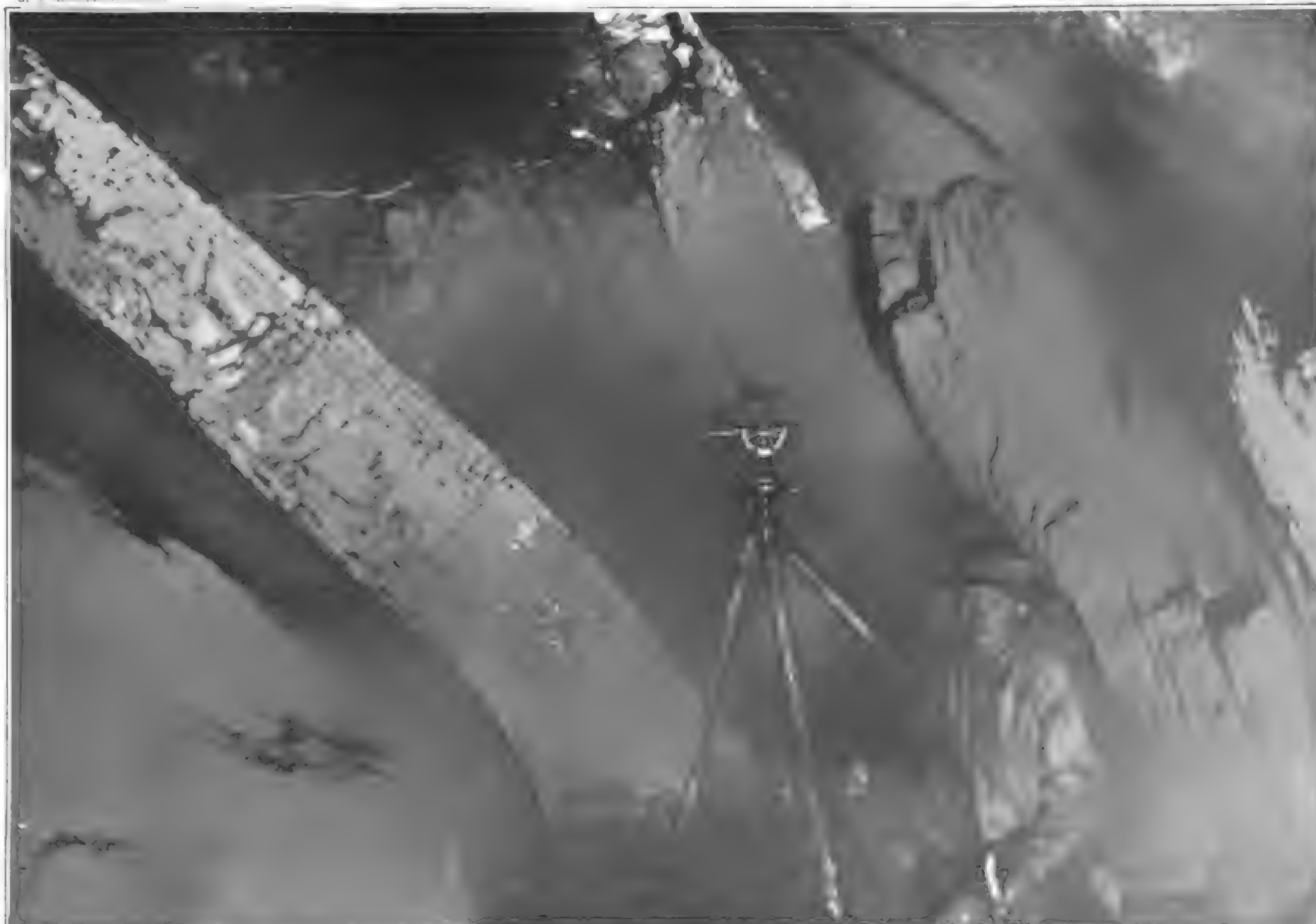
CHAPTER XI.

VEIN STRUCTURE AND PAY SHOOTS.

STRUCTURE OF THE VEINS.

The character of the fissure determines, to a great extent, the structure of the vein. The simplest form of a fissure is a joint plane, such as is seen in regions of intense sheeting about the Lecompton and Canada Hill mines or in the seam belt of the Red Hill west of the Nevada City mine. On some of these joints there is a narrow line of quartz, accompanied by a slight bleaching of the rock on each side. Certain of these breaks along the joint planes may be more pronounced and extensive, or one larger break may be produced instead of a series of smaller ones. In such case there is usually a more noticeable movement along the fault plane, and the sliding of two irregular surfaces on each other produced more or less continuous open spaces, which were subsequently filled with quartz. This is the character of the Idaho-Maryland, the Mountaineer, and the Omaha veins, for instance, and is well illustrated by Pl. XI. The vein here consists simply of a filling of white quartz 2 to 3 feet wide between two parallel surfaces. The regularity is usually not maintained over a large extent of the vein. It is extremely common to find local pinches, and sometimes the vein is found to close down to a mere seam in whole levels, above and below which good ore is found. Again, in places the vein loses its regular character by reason of local fracturing and brecciating of the hanging wall. A typical occurrence of this kind is shown on Pl. XII (see also detailed descriptions, Idaho vein, p. 229). To this first relatively simple type many veins in the district belong.

Another class of veins, to which the Empire, the North Star, and many others belong, presents a somewhat more complicated structure. In them the simple clean break is replaced by a compound one, in which two or more distinct fractures have been formed at a distance of a few feet; between these lies more or less crushed and brecciated rock. Quartz-filled fissures lie along the hanging wall or along the foot wall, or along any minor break in the rock between the walls. The latter may more or less distinctly assume the character of a breccia cemented by quartz. It is usual, however, to find the main quartz vein close to the hanging wall. The rock between the walls is always most altered by metasomatic processes. The little veins and seams, sometimes, as on Pl. XIII, forming a network in it, are predominantly composed of calcite. This structure is illustrated by Pls. XIII, XIV, and XV. See



MARYLAND VEIN, ON THE 1,400-FOOT LEVEL.

Vein 2½ feet thick and very rich

MARYLAND VEIN, STOPE ABOVE 1,500-FOOT LEVEL.

NORTH STAR VEIN, NEAR 1,700 FOOT LEVEL, SHOWING 2-FOOT QUARTZ VEIN AT HANGING WALL AND ALTERED DIABASE WITH CALCITE SEAMS BELOW.

also fig. 18, Pittsburg vein, p. 202. The hanging wall is generally more distinct than the foot wall.

In the examples mentioned thus far, the evidence of extensive movement along the vein is less pronounced, the brecciated structures indicating a sudden short break rather than a long-continued grinding of the walls against each other. Schistose structure, due to the latter condition, occurs in places—for instance, along both walls in the Idaho-Maryland and the North Star, but only in the Ural and Merrifield veins does it becomes prominent. In these the quartz, where the vein is simple, is adjoined by several feet of schistose rocks, produced by the pressure and movement along the fissure; where the vein is compound, smaller streaks and seams of quartz are distributed through this schist, which may attain a width of 20 feet or more.

The width of the quartz vein may in some cases attain several feet. On the Merrifield vein a width of 6 and 10 feet of solid quartz has been observed, and in the Ural vein, in the Nevada City mine, one smaller ore body reached 12 feet. Ordinarily 2 to 3 feet is the width of the Merrifield and Ural veins. The other veins in the Nevada City district will not average 2 feet in width. With a few exceptions, the veins in the Banner Hill district are narrow, averaging hardly more than 18 inches. The Grass Valley veins are narrow, excepting the Idaho-Maryland, Gold Point, and a few more, and scarcely average 18 inches in width. Many veins, such as Houston Hill and Norambagua, have paid well with an average width of 6 inches, or even less. Seams with only an inch or two of quartz will sometimes contain an extraordinary amount of gold.

In the comparatively soft black slates of the Mariposa formation, along the Mother lode, a vein structure frequently appears, which, though not occurring in the region described, may be mentioned for comparison. The vein lies along the contact of black slate and diabase, separated by a distinct, and often polished, hanging wall of the latter. There is rarely a continuous and well-defined vein, but the black slate is crushed, sometimes over a width of 20 feet, or even more, and stringers of quartz penetrate it in all directions, in the manner shown on Pl. XVI, from a photograph by Mr. N. W. Emmens. Again, the pay is contained in the quartz, but it is, of course, necessary to mine the whole width of the stringer zone, which thus furnishes large masses of a low-grade ore. The plate shows, in addition, a curve of the principal mass of quartz, which may be due to movement subsequent to deposition.

THE PAY SHOOTS.

GENERAL FEATURES.

The rich quartz may occur in entirely irregular patches and areas on the plane of the vein. It is much more common, however, to find it occurring in more or less regular bodies, usually referred to as "ore shoots." Extremely rich masses of small extent and irregular form are

called "pockets," or when they have a regular, long-drawn form, "chimneys." Pockets with local accumulation of coarse free gold often occur in the pay shoots of the Grass Valley mines; the Peabody and also the Gold Hill mines in Grass Valley, the Sneath and Clay and the Mohawk near Nevada City are examples of such pocket veins. The quartz between the pockets may be almost barren or it may contain a fair-grade ore.

In most of the veins the development of quartz is not confined to the ore shoots. In other words, the vein preserves its general character over a large area, but only in part of it—the ore shoot—does the quartz contain enough gold to be extracted as an ore. In another and smaller class of veins, represented by the Nevada City, the Omaha, the Pittsburg, and others, all quartz occurring in the vein is good ore, and outside of the ore shoots the vein closes down to a seam. The question what grade of quartz is regarded as ore of course influences the extent of the shoots. In the districts here considered, everything above $6 per ton, the average cost of deep mining and milling, is included as ore, although in most mines this tenor is considerably exceeded.

FORM OF THE SHOOTS.

A few characteristic ore shoots are shown on Pls. XVII and XVIII, and others will be found in the detailed descriptions. In general, the shoot has an elongated shape, and forms an angle with the horizontal plane, which generally differs, though usually not greatly, from the dip of the vein. In other words, the shoot usually pitches at a steep angle on the plane of the vein. The following law appears to govern the general direction: *The shoot will, as a rule, pitch to the left of an observer standing on the apex of the vein and looking down in the direction of the dip.*[1]

In a number of veins there is, to be sure, no great regularity, or the ore shoot will often be found to dip at the same angle as the vein, but the number of instances in which the above rule is applicable renders it indubitable that this occurrence of the ore is the result of certain conditions as yet not fully understood. This law holds good in a great many mining districts of the Gold Belt outside of these here described, and it is certainly worthy of close scrutiny. Pay shoots dipping in opposite direction from that stated above are said to occur on the Gold Flat vein, the Slate Ledge vein, and the Little Diamond vein.

No relation could be established between the direction of the pay shoots and the direction of the striation on the walls. According to the so-called Clayton's law, they should coincide.

Pay shoots may cross from one formation into another without change. As examples may be cited Providence mine, Merrifield vein, in the Nevada City district; Union vein, Banner Hill district; Empire vein

[1] While this law has been well known by the miners for many years, yet it has not been distinctly stated before. In Bean's Directory it is applied to the north-and-south veins only (p. 55, Statement by T. H. Rolfe).

NORTH STAR VEIN, NEAR 1,800-FOOT LEVEL, SHOWING QUARTZ VEIN IN BRECCIATED AND ALTERED DIABASE.

OPHIR HILL VEIN, EMPIRE MINE, NEAR 1,600-FOOT LEVEL, SHOWING SEVERAL SMALLER VEINS BETWEEN FOOT AND HANGING WALLS.

BUNKER HILL VEIN, AMADOR COUNTY, CALIFORNIA; STOPES ABOVE 300-FOOT LEVEL, SHOWING VEIN SPLIT UP INTO SEAMS IN BLACK, CRUSHED CLAY-SLATE.

and Granite Hill vein, Grass Valley district. The apex of most of the large pay shoots discovered very naturally crops on the surface, but this is not an invariable rule. The apex of the Eureka-Idaho shoot, for instance, was found at a depth of about 100 feet; the beginning of the main ore shoot of W. Y. O. D. was not found till a depth of several hundred feet was reached; neither did the rich shoot on the Ural vein in the Providence appear on the surface. The possibility of finding a new ore shoot at any depth must be conceded.

While the largest ore shoots may be from several hundred up to 2,000 feet wide and up to 3,000 feet long, there are many shoots on the smaller veins which have a much less width and length. These smaller shoots sometimes go down to great depth, but are in general less to be depended on for permanence in depth than wider ore bodies. Even the small chimneys and pockets in the seam belt of Red Hill are stated to follow the law stated above.

The North Star workings (Pl. XXIII) form an excellent example of a large ore shoot following the same law. In this case the main shoot is composed of a number of smaller ore bodies with similar trend, separated by spaces in which the vein has closed down to a seam. The Eureka-Idaho ore shoot (fig. 27, p. 229) is unique in its long extent and flat dip; this is also probably the most uniform shoot in the district, containing relatively few barren places or pinches and having a known length of over 3,000 feet. No relation of the ore shoots to the cross fissures could be found. Indeed, the latter are generally later than the ore fissures and do not carry quartz. Intersection of two veins—a phenomenon not very often observed—will sometimes, but not always, produce richer ore bodies.

PERMANENCE IN DEPTH.

This question is one of the highest importance, bringing up the whole future of the industry of gold mining.

It is certain that the experience with many of the smaller bodies of ore is that they give out or pinch at varying depth.[1] Others, again, have continued to the greatest depth at which the exploitation of the mines has been carried on. Similar relations prevail in regard to the large ore shoots. While some have been found to cease in depth—the Sierra Buttes mine, in Sierra County, being a well-authenticated example—others continue to the deepest levels as strong as or stronger than in the upper part of the mine, the Kennedy mine, in Amador County, being an example of the latter class.

The frequent local irregularities of most shoots make it very difficult to affirm, without extensive explorations, that the end of any certain ore body has been reached. Owing to the habit of immediately distributing all of the profit as dividends, reserve funds for exploratory

[1] This discussion refers only to the ores below the zone of oxidation. It is well known that the ores above the water level are, from causes of local concentration, richer than those not altered, and an impoverishment may generally be expected below the water level.

work are seldom available, and a local impoverishment in a level has often been sufficient to close a good mine. Experience with the large shoots is still insufficient for safe generalization.

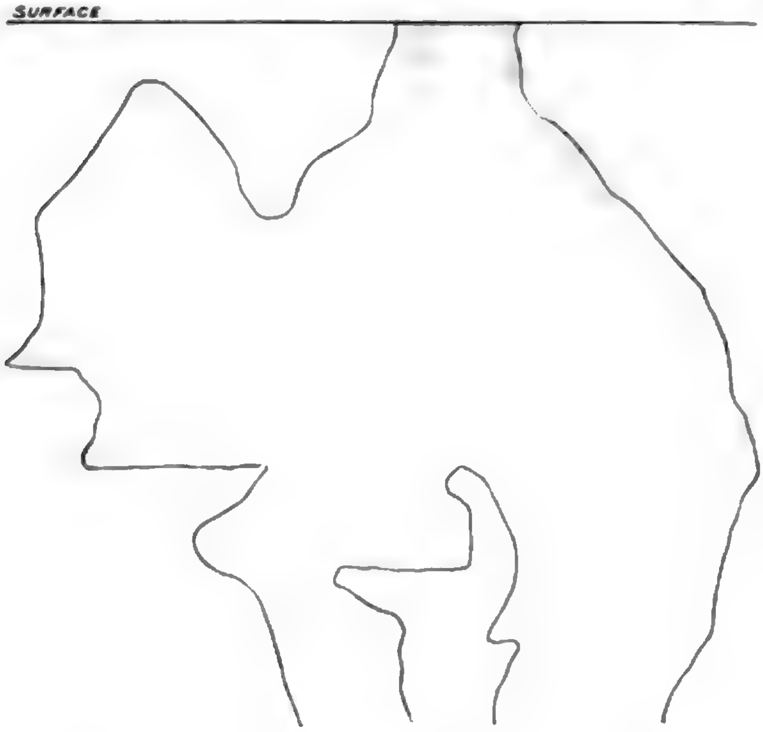
The ore shoot of the North Star extends for a distance of about 2,500 feet in depth, measured along the plane of the vein. When approaching the sedimentary area to the west, it was cut off or divided into stringers. Still, the explorations are scarcely extensive enough to affirm that its end has been reached; its continuation may be found, or a parallel shoot may be found in depth. In the case of the large Empire shoot a complication has arisen, due to a split of the main vein, reducing the tenor of the ore by dividing it on three veins. The Eureka-Idaho shoot has held its own remarkably well and uniformly over a distance of over 5,000 feet, though the richest part of it was probably found in the Eureka and the western part of the Idaho ground.

High-grade ore is now mined in the Maryland mine on the same shoot at a vertical depth of 1,500 feet, and a small ore shoot was found near the bottom of the Idaho shaft at a depth of 2,200 feet. As gold-quartz veins of fair grade occur near the summit of Banner Hill, at an elevation of 3,800 feet above the sea, or 3,500 feet above the bottom of the Idaho shaft, we have in this district within short distance a vertical interval of 3,500 feet within which there is no evidence of any gradual change in the character or quality of the ore. Again, in the vicinity of Washington, Nevada County, excellent quartz is mined 600 feet below the river level, in the Eagle Bird mine, and on the ridges north of the river 2,000 feet above the river level. In this distance there are no distinct differences in the quality of the ore.

Many smaller veins carry only one ore shoot, but in the larger fissures there are generally several of them. There is a strong probability that in such veins thorough exploration laterally or in depth will develop new bodies of ore if the one on which exploitation has been carried on is found to pinch out. The question will naturally arise as to whether, with increased depth and cost of mining, it will be a good venture to carry on the necessary dead work. This will have to be decided by the record of the mine and the character of the fissure.

It is generally conceded now that fissures are, comparatively speaking, surface phenomena, and that below a certain depth, where plasticity and flow of rocks under pressure come into play, open spaces can not exist. This limit Professor Heim, for instance, places at 16,000 feet, while Professor Van Hise, basing his consideration on the strength of rocks, arrives at 33,000 feet as the maximum limit for hard rocks in which fissures can exist. Even the lowest of these estimates far exceeds the depth of practicable mining. But it is not likely that all fissures continue until that limit. On a small scale the discontinuance of fissures may be observed in extensive sheeted outcrops. It is also an incontestable fact that many small veins[1] close up in depth, while

[1] These small fissures, though not continuous in depth, may easily have been accessible to the thermal waters by cross seams connecting them with the larger conduits.

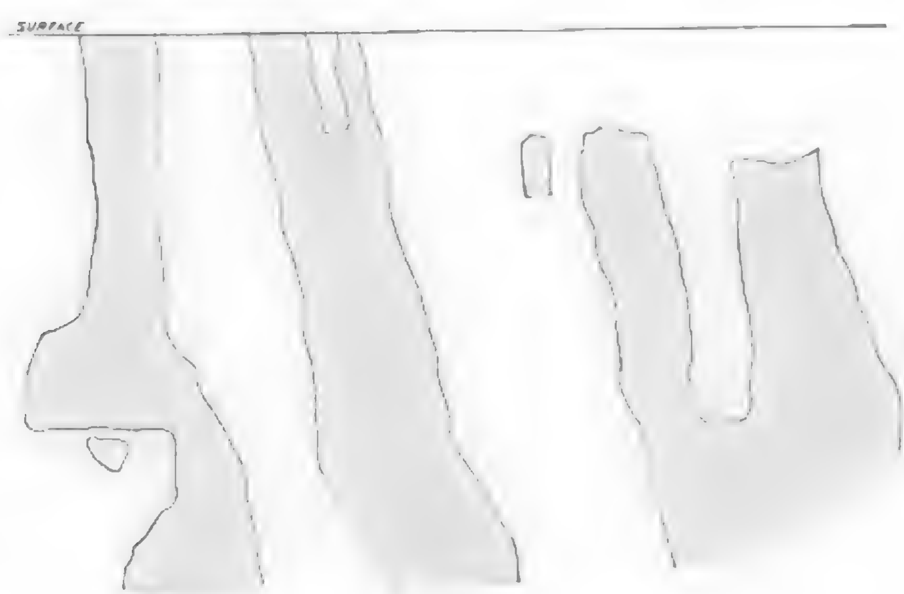


a

b

ORE SHOOTS OF NEVADA CITY AND GRASS VALLEY MINES.

a



b

ORE SHOOTS OF NEVADA CITY AND GRASS VALLEY MINES.

others continue unchanged. In considering the probable permanency of a given vein, its general character must be taken into consideration. Continuous well-defined outcrops and wide bodies of quartz are in general good indications of the maintenance in depth, as is also any evidence of strong faulting and movement. Some quite extensive veins, though, have relatively short outcrops. Thus, the Eureka-Idaho practically shows croppings only for a distance of 2,000 feet, but within that distance they are very prominent. Those of the North Star are less than 2,000 feet long. From the developments to the east along the Omaha system it is pretty certain that the vein does not continue far across in that direction. A fissure which can be definitely proved to extend only a short distance will in all probability be found to be correspondingly limited in depth. In regard to probable permanency of the vein in depth, the Ural and Merrifield, along which extensive faulting has taken place, stand first in the districts.

In scrutinizing the scant statistics of the production, in tons and value, of the Grass Valley district, it can not be denied that they show on the whole a distinct decrease. There is also a distinct decrease in the average value of the ore. It is not safe, however, to draw too far-reaching conclusions from these data, because there are many factors involved: The cost of treatment and mining has decreased greatly by reason of the modern methods introduced, and more low-grade ores are now milled than formerly; nor are there any rich surface ores left to swell the grade.

Leaving the difficult question of deep mining out of consideration, there are, however, in both districts a large number of veins which have been only slightly developed, but which with improved methods may be converted into paying mines. The development of these will probably maintain the production of the district for many years in the future, even if no new ore bodies are discovered in the old mines.

It can be confidently stated that there is no gradual diminution of the tenor of the ore in the pay shoots below the zone of surface decomposition. Within the same shoot there may be many and great variations of the tenor, but there is certainly no gradual decrease of it from the surface down. This important fact has been previously stated by those conversant with the veins, such as Professor Silliman and Mr. J. A. Phillips. The statements to the contrary, for instance, by Mr. Laur or Mr. Reyer (see literature in Chapter I, pp. 16–17), are due to imperfect acquaintance with the facts and generalization from insufficient premises.

CROSS-CUTTING.

As a means of finding new and parallel veins, cross-cutting is frequently advisable, especially in those parts where strong sheeting of the rocks prevails. In the larger part of these districts, however, a series of parallel, distinct veins appear instead of the sheeting. These veins are nearly always traceable on the ground, and in such cases cross-cutting has rarely developed veins not known already on the surface.

CHAPTER XII.

THE FISSURE SYSTEMS.

That the veins are practically independent of the geological structure and that the strike and dip vary greatly are facts that have already been emphasized. However, certain systems with definite relations between one another may be easily recognized.

THE VEINS WITH A GENERAL EAST-WEST STRIKE.

Many of the most important deposits of the district are found on veins having a general east-west strike, which may be grouped in a number of subclasses:

The Willow Valley group.—This comprises the veins with moderate northerly or, more rarely, southerly dip (as the Federal Loan), occurring along Deer Creek, in the Banner Hill district, from the Texas mine to the Constitution. The strike is generally a little north of east. The central eastern part of this system is intimately connected with an extensive system of sheeting crossing the granodiorite contact. Nowhere, indeed, can the close connection of the veins with the sheeting of the country rock be better demonstrated, the veins simply forming the most prominent of the joint planes. The facts noted in the detailed descriptions of the Federal Loan and the Never Sweat mines indicate the intimate relation and contemporaneous origin of the veins dipping north and those dipping south. It will be suitable to designate groups of veins with the same strike but symmetrically opposite dip as *conjugated* systems.[1]

A line of veins with east-west strike and moderate to flat southerly dip extends from the Mayflower and Beckman to the Mohigan, south of the granite contact, and evidently belongs to this group.

The North Star group.—The strike in this group, which is developed only in the vicinity of the North Star mine, is generally WNW., and the dip moderately to extremely flat either north or south. The extremely intimate connection between the veins of these conjugated systems is again made clear by the developments in the New Rocky Bar (Pl. XXII), where two veins, one dipping north and the other south, join in a curved arch filled with quartz.

The St. Louis group.—Represented chiefly on the Banner Hill sheet by the St. Louis, Big Blue, and other veins, this group is distinguished by a strike about parallel to that of the Willow Valley vein, that is,

[1] Daubrée, Géologie experimentale, p. 320.

east-west or WSW.-ENE. The dip is, however, very steep, approaching 90°, and generally a little toward the north; the veins are often wide, but generally of low grade. In the Grass Valley district and in the vicinity of the Pittsburg mine and at other places in the Nevada City district there occurs a series of joint planes and fissures, rarely filled with quartz, which cut and sometimes fault the veins belonging to other systems. The dip is steep, to the north or south, and the strike in most cases ENE. It is probable that these "crossings," as they are locally called, belong to the St. Louis group. That they are still open fissures is indicated by the ease with which water circulates on them; they are, in fact, the principal subterranean watercourses, and in the vicinity where they prevail the deepest mines will drain all the smaller ones in the neighborhood.

The Idaho-Orleans group.—This important division is characterized by a strike varying between east-west and WNW.-ESE. and a steep, generally southerly, dip. The latter is, however, sometimes also at steep angles to the north, and, indeed, the Eureka vein is said to change from a southerly to a northerly dip in its western extension. The veins belonging to this group are strong, wide, and well defined. The Idaho, Orleans, Coe, Gold Point, and Imperial (on Deer Creek, west of the limits of the sheets) are illustrations. In which group the Spring Hill, Alpha, and Kentucky should be counted is doubtful. Toward the east the veins belonging to this group acquire a more decided northwesterly strike. In this group again, as in the others, there are indications of two conjugated systems with dips in symmetrically opposite directions.

THE VEINS WITH A GENERAL NORTH-SOUTH STRIKE.

To this class the majority of the veins belong, both in the Nevada City and the Grass Valley district. While the strike may be subject to variations extending from NNW. to NNE., there does not seem to be any reason for separating these veins into more than two groups.

The Providence group.—Dip, medium to flat to the east. These veins are represented in the Banner Hill district by the Banner Hill system, as well as by the Buckeye, Grant, Enterprise, and others. In the Nevada City district they are extensively represented by many smaller veins and by the important system of six or seven veins, radiating from a point near Town Talk toward NNW. and NNE. and then again all bending toward NNW. The Ural vein makes the most sudden bend, changing to a direction practically parallel to that of the Orleans-Idaho system. The Ural and Merrifield veins are among the most important in the district, and extensive faulting has without doubt occurred on them.

In the Grass Valley district veins dipping east at flat angles are found on Gold Hill, Massachusetts Hill, and along the foot of Osborne Hill. They are generally narrow and often very rich. Sheeting parallel to this group is noted along Wolf Creek at the Larimer mine.

The Omaha-Empire group.—Dip, medium to flat to the west. This group is also of great importance. In the Banner Hill district it is represented by the Deadwood, Murchie, and Canada Hill veins, at the latter place accompanied by extensive sheeting of the granodiorite: in the Nevada City district only a few larger veins, such as the Sneath & Clay and the Mohawk, dip to the west, but in the seam belt of Red Hill, west of the Nevada City mine, a great number of seams and narrow veins dip in that direction. The direction has been, however, changed so much to the northwest, following the great bend of the Ural vein, that the identification with the north-south class of veins becomes doubtful. In the Grass Valley district this group is abundantly represented by the Dromedary vein, continued southward by the Omaha system, and by the great Empire-Osborne Hill system of linked veins, in which the general direction has changed to some degrees west of north. Extensive sheeting parallel to this group of veins is shown in the northwestern part of Grass Valley (Pl. III).

Considered together, these two groups may again be regarded as conjugated systems of fractures. The exposures at certain mines, such as the Pennsylvania and W. Y. O. D., show the very intimate connection existing between the two groups and their contemporaneous origin, the quartz veins of one group sometimes falling back on fissures belonging to the other.

In each of the different groups of the east-west veins, as well as in the north-south veins, there are thus two conjugated and apparently contemporaneous systems with approximately similar dip in opposite directions.

INTERSECTION, FAULTING, AND RELATIVE AGE.

Intersection and faulting are not of frequent occurrence, and the opportunities for examining such phenomena from personal inspection are not abundant during one short season of investigation. The following facts are gathered from the detailed descriptions:

Veins of the Willow Valley group fault the Deadwood vein, which dips to the west, producing a reversed fault.

The Big Blue cuts through the Lone Star vein, dipping west. The St. Louis vein faults the Canada Hill, dipping west, and the fault is again a reversed one. Several east-west veins about parallel to the St. Louis fault the Floyd, dipping east, and the Beckman, dipping south. The movement is apparently a relative down-throw of the south side, diagonally inclined toward the east.

The Nevada County and the Mountaineer veins are faulted by east-west veins. The Pittsburg and the Gold Flat veins are repeatedly cut and somewhat faulted by perpendicular east-west seams, resulting in a relative downthrow of the north side.

In the Grass Valley district the barren cross-seams with steep dip and ENE. strike frequently fault the veins of the Empire and North

Star groups a little, the movement being generally in the nature of a reversed fault. A bending of the faulted vein is very frequent.

The faults are sometimes effected by single fault planes, but it is more frequent to find several parallel planes a short distance apart, on which gradually decreasing differential movement has taken place.

Summing up the evidence, the results obtained are:

That the north-south contemporaneous conjugated systems are the oldest veins;

That the veins of the St. Louis group are the most recent, and that the Grass Valley "crossings," though not as a rule filled with quartz, belong to this group;

That the veins of the Willow Valley group are more recent than the north-south veins, but older than the St. Louis veins;

That the North Star group is probably contemporaneous with the Willow Valley group;

That there is no direct evidence of the relative age of the Orleans-Idaho system, but that it is probably of the same age as the north-south veins;

That reversed (overthrust) faults, with a relative upward movement of the hanging wall, are prevalent. In the Merrifield and Ural veins the throw measured along the hade of the fault probably exceeds 1,000 feet, while in all other known cases the displacement is relatively small, possibly excepting the Idaho-Maryland vein.

RELATION OF THE VEIN SYSTEMS TO GEOLOGICAL STRUCTURE.

Considered in detail, no connection can be said to exist between the distribution of the veins and vein systems and the geological structure. Veins of the different systems occur in practically all the diverse rocks and cross all principal contacts without being influenced by them. They do not, as a rule, follow any contacts except where subsequent faulting has made the plane of the vein the contact plane. From this statement should, however, be excepted certain veins in serpentine, such as the Kentucky and in part also the Eureka-Idaho, which show an inclination to follow the line of diabase dikes in the first-named rock.

The veins do not, except locally, follow the schistosity in strike, and apparently never in dip. The different degree of resistance of rocks to deformation of course influences the fissures to some extent, but considering the great diversity of rock types this influence must be characterized as slight.

The fissures are more apt to be straight and clear-cut in hard, even-grained rocks, such as diabase and granodiorite, being splintery and irregular and easily breaking up into brecciated zones in argillite. Fissures in serpentine rarely continue unbroken for a long distance; in fact, to enter serpentine seems fatal to the continuation of most veins.

It might be said in a general way that the veins of the Willow Valley group are narrow and contain rich ore, much sulphurets, and a

considerable percentage of silver, but certain north-south veins in the same district have the same characteristics. The Idaho-Orleans group may be characterized in general as heavy veins with but little sulphurets and little silver. On the whole, the rules which might be adduced are very vague and indefinite.

Nor can any distinct influence of the country rock be said to exist. Veins occur in granodiorite, diorite, gabbro, pyroxenite, and serpentine; in diabase, porphyritic diabase, and porphyrites; in amphibolitic, chloritic, and micaceous schists; in clay-slate, sandstone, siliceous argillite, and contact breccias. In scrutinizing closely the data in the detailed description it is found that the metasomatic processes have been practically identical in all these rocks, and that the character of the filling—that is, the principal ore—varies greatly, but is not constant for the same rock; it even varies in different parts of the same vein in the same rock. Veins in granodiorite and argillite often carry much sulphurets and silver, veins in diabase little of these substances, and of the former chiefly pyrites and galena. But these tentative rules have so many exceptions that their value becomes extremely problematical.

On the other hand, the influence of *locality* is strongly pronounced. The Willow Valley and Canada Hill veins form one group, the City veins another, the Providence-Mountaineer veins still another. The southern end of the Osborne Hill system is characterized by arsenopyrite, as are the Forest Spring veins, in greatly differing rocks.

Leaving the details and looking at the occurrence of the gold veins at Nevada City and Grass Valley, together with those of the surrounding country, the great concentration of deposits in the district described is the first striking fact.

To the west there extends down to the foothills vast areas of granodiorite, diorites, and porphyrites, in which only scattered quartz veins occur. To the south the almost barren augite-porphyrites reach down to Auburn. Toward the north stretches the granodiorite massif of Nevada City–San Juan, containing many placer deposits, but few quartz veins. Eastward, finally, are the sedimentary clay-slates of the Calaveras formation, on which lie many placer deposits and which contain many small, scattered veins, but no important vein systems until the vicinity of Washington, 15 miles east, is reached.

Between these relatively barren areas and the crowded fissure systems of Nevada City and Grass Valley, filled with rich gold ores, the contrast is very strong. Considering the veins of Banner Hill and the Nevada City district as a whole, it can not fail to strike any observer that, while occurring in any of the several rocks of the vicinity, they are chiefly grouped along the semicircular contact of granodiorite with the older rocks.

To the south of this zone is a comparatively barren belt until the Grass Valley district is reached. Here again the veins show some relation to the smaller massif of granodiorite, occurring on both sides of it and in it along its whole extent.

ORIGIN OF THE FISSURE SYSTEMS.

The first point emphasized by the study of the veins is the practical identity of the joints and sheets with the vein fissures, the only difference being one of degree of dislocation. The second is that schistosity of the rocks adjoining the veins may to some extent be produced by the same forces which produced the veins and joints. A third is the fact that each group of veins contains two sub-groups, which, with the same strike, dip in opposite and symmetrical directions, the two sub-groups being designated *conjugated* fractures.

The explanations of the joints, fissures, and occasionally accompanying schistose structure appear to be furnished by certain experiments by Daubrée[1] and by the mathematical deductions of Becker.[2]

It is plain that the formation of joints and fissures and the movement produced on them are due to mechanical causes. Tensile stresses—contraction and dilation—can not, as shown by Becker, explain these phenomena, for they result in the formation of curved and broken, and not extensive plane, partings; the fissures and joints would be gaping and there could be no slickensides on the parted surfaces.

Torsional stress can, according to the well-known experiments of Daubrée, produce two main sets of fractures approximately at right angles to each other, and usually at nearly 45° to the axis of torsion, the minor fractures often showing divergent directions. This explanation has been proposed for fissure systems—for instance, those on which the metalliferous veins of the Hartz are found. A closer examination shows, however, that the fissures produced by the experiments are nearly always curved and warped surfaces, and not approximate planes, as are the fissures here under consideration.

Becker[3] considers the experiments on the torsion of glass equivalent to the application of a system of tensions peculiarly distributed, and that the fissures produced in any mass physically resembling glass will exhibit the peculiarities of tensional fractures, together with some marked characteristics of their own.

This theory rejected for the present case, the only adequate one remaining is that of direct pressure, according to which the joints and fissures are produced by shearing stress. This, indeed, appears to explain perfectly all the facts observed, and especially the frequency of overthrust movements or reversed faults. In Daubrée's beautiful experiment[4] on a mass of beeswax and resin two conjugated systems of joints and fissures were formed, making an angle of about 45° with the line of pressure, and similar results have been obtained by testing cubes of building stones. These conjugated systems, which are approximately at right angles to each other, reproduce very closely the north-and-south veins of the districts here considered, with the

[1] Études synthétiques de géologie expérimentale, p. 316.

[2] Finite homogeneous strain, etc.: Bull. Geol. Soc. Am., Vol. IV, 1893, p. 13.

[3] The torsional theory of joints. Trans. Am. Inst. Min. Eng., February, 1894.

[4] Loc. cit.

exception that the lateral angle between the planes dipping east and those dipping west is generally somewhat less than 90°. The east-west fissure systems are more irregular, the angles between the two sets of planes varying from 20° up to nearly 180°, and are, at least in part, later than the former systems.

It is thus most probable that the fissure systems have been produced by a succession of compressive stresses applied in different directions, chiefly from east to west and from north to south.

In the study of this question the fact should be borne in mind that not only vertical but to some extent also horizontal displacements have occurred, as indicated by the often inclined direction of the striations on the wall. The schistose structure often accompanying the veins appears, in conformity with Becker's view, due to relative tangential movement in the same direction as the fissure, but not reaching the limit of cohesion of the rocks.

TEMPERATURE IN THE MINES.

But few of the mines of Nevada City and Grass Valley have reached a vertical depth of over 1,000 feet, and the temperature of the air in the upper workings ordinarily ranges from 55° to 60° F. The Idaho-Maryland has at present attained greater depth than any other, and it seemed of some interest to obtain data from it as to the increase of temperature in the lower levels, even if the methods adopted were crude by necessity. A 2-foot thermometer was procured from Mr. A. Lietz, of San Francisco, and by him carefully compared with a standard. The graduation was in Fahrenheit. The instrument was inserted in bore-holes 2 to 3 feet deep, the opening carefully stopped up, with the neck of the thermometer protruding, so that it could be read by drawing it out a few inches. The thermometer was allowed to remain till a constant temperature was registered, usually about half an hour. The tests were made June 14, 1894. A bore-hole was first made in the drain tunnel, 250 feet from the mouth and about 30 feet below the collar of the shaft. The hole was 3 feet deep and in gabbro, the rock being very damp. Temperature in drift, +57½° F.=+14.2° C. Temperature in bore-hole, +53½° F.=+11.9° C.

The next observations were taken in the face of the drift on the fifteenth level, 1,523 feet vertically below the drain tunnel. The deepest point attained in the mine is 2,151 feet below the drain tunnel, or 2,181 feet below the collar of the shaft, but no levels below 1,600 feet are now accessible.

A damp bore-hole on level 15 gave the temperature of +66° F., or +18.9° C. The water on this level had a temperature of +62° F., or +16.7° C.

Further observations were made in the stope 40 feet above level 15, or 1,483 feet below the drain tunnel. A wet bore-hole in quartz gave the same results as 40 feet below, or +18.9° C. A dry bore-hole in

quartz gave a little higher result, +67¼° F., or +19.6° C. The air in the stopes had a temperature of +69° to +70° F., or about +20° C.

Taking the damp bore-holes in the drain tunnel and on the fifteenth level for comparison, we have an increase of 12½° F., or 7° C., in a depth of 1,523 feet. Supposing it to be uniform, this is equivalent to an increase of 0.82° F. per 100 feet, or 1.5° C. per 100 meters. In other words, it is equivalent to an increase of 1° F. per 122 feet, or 1° C. per 66 meters. This is probably the most nearly correct value for the increment. Taking, however, the difference between the dry bore-hole in the stope and the damp one in the drain tunnel, a difference of 13.75° F. in 1,483 feet, or of 7.7° C. in 452 meters, is obtained. This corresponds to an increase of 0.93° F. per 100 feet, or of 1.7° C. per 100 meters. In other words, it is equivalent to an increment of 1° F. in 107 feet, or 1° C. in 59 meters.

In discussing these results it should first be stated that the temperature of 53.5° F. of the rock obtained in the drain tunnel, 30 feet below the surface, is apparently considerably different from the mean annual temperature of the air. There are no temperature data available from Grass Valley so far as I know, but the records from Colfax, Cal., 14 miles away and at nearly the same elevation, viz. 2,500 feet, cover a number of years and give a result of nearly 59° F. An average annual temperature of 53° F. is not reached until at an elevation of about 4,000 feet. It is further clearly apparent that the increment observed is very small compared with the values usually obtained. Even assuming the larger increment of about 1° F. per 107 feet, the temperature would only be 91° at a depth of 4,000 feet.

Professor Prestwich[1] gives the mean increment for coal mines as 1° F. per 49.5 feet; for other mines, per 43.2 feet, and for artesian wells, per 50 feet. Different localities show, however, greatly diverging results. Professor Hallock found in the well at Wheeling, W. Va.,[2] 4,500 feet deep, an increase of 1° F. for 80 to 90 feet in the upper part of the well, and of 60 feet in the lower part. Mr. Alexander Agassiz[3] found recently in the Calumet and Hecla copper mine, Michigan, 4,700 feet deep, an average increase of 1° F. per 224 feet, or 1° C. per 122 meters. This is decidedly the slowest increase noted anywhere, but the temperature at a depth of 100 feet appears in this case to be much higher than the average temperature of the air in Michigan. If the latter is contrasted with the temperature in depth a much more rapid increase is obtained. It is to be hoped that more observations will be made on the temperature of deep mines in the Gold Belt. Many of them appear to have a remarkably low temperature considering the depth, and it was this observation that led to the experiments here recorded.

---

[1] Proc. Royal Soc. London. Vol. XLI, 1886, pp. 1-116.
[2] Am. Jour. Sci., Vol. XLIII, 1892, p. 234.
[3] Am. Jour. Sci., Vol. L, Dec., 1895, p. 503.

CHAPTER XIII.

GENESIS OF THE VEINS.

AQUEOUS DEPOSITION CERTAIN.

It has been established in former chapters that the veins occur on fissure systems in the rocks, produced by a compressive stress, and that these fissure systems are later than any part of the pre-Cretaceous rock system. The substances due to vein formation are shown to be in part country rock altered by metasomatic processes, in part fillings of pre-existing cavities, the ores proper consisting almost exclusively of the latter class.

It has been assumed that these substances are due to the action of aqueous agencies, or, more definitely, to certain solutions containing, dissolved, the various metals and elements which are now found on the veins. The formation of quartz veins by these agencies is now so generally accepted that it is only necessary to point briefly to the facts indicating such an origin, the only remaining alternatives being an origin by sublimation or by gaseous emanation. Among these facts are the character of alteration of the country rock, including the removal of certain elements, such as sodium, the formation of hydrous minerals, and the occurrence of extremely abundant fluid inclusions in the quartz.

Admitting the aqueous deposition as a fact, the problems offering themselves are the character of the solutions and their origin, as well as the cause of deposition.

CHARACTER OF THE SOLUTIONS.

The filling of the veins, and especially the metasomatic rocks accompanying them, gives direct evidence as to the character of the solutions. The quartz indicates, of course, that silica must have formed an important constituent of the solution. The abundant carbonates and sericite in the altered wall rock show that carbon dioxide or alkaline carbonates, probably also calcic carbonate as well as potassium, must have been contained in the water. A portion of cl ar, massive quartz without sulphurets, from the fourteenth level of the Merrifield vein, Providence mine, was examined by Mr. George Steiger for substances soluble in boiling water, with the result that small quantities of sulphates and chlorides were found, which in all probability were contained in the fluid inclusion of the quartz. Sulphates must evidently also have been

contained in the waters. Sodium would also be expected from the vigorous leaching of this metal indicated by the metasomatic processes.

The analyses of the ascending waters found on the veins, noted in the chapter on the contents of the veins, are of interest as showing to some extent the character which, according to the above, would be expected of the vein-forming solutions. They are, to be sure, cold and weak mineral waters, lacking in the amount of carbon dioxide and hydrogen sulphide which the vein-forming solutions must have possessed, and perhaps more the result of the leaching of the already formed vein, but the relative abundance of the carbonates and silica is suggestive, as is also the small amount of chlorides and sulphates.

Waters which have exercised such a powerful metasomatic influence on the rocks in the vicinity of the veins and contained such large quantities of carbon dioxide as are required by the facts of the metasomatism, are not known to occur in nature except as ascending, usually thermal springs. That such was the character of the vein-forming solution is a conclusion toward which not only one but several lines of reasoning lead.

That the waters were thermal is also indicated by the depth at which the deposition must have been proceeding. It is quite clear that the cropping of the veins—their apex—at the time of vein formation must have been far above the Neocene surface. The amount of their pre-Neocene erosion is difficult to estimate; from the geological history outlined above it is apparent that vast masses of effusive rocks covered the region previous to the granitic batholitic eruptions, and that the veins were formed immediately after these intrusions of abyssal rocks. From these data a guess may be made that about three or four thousand feet represents the thickness of rocks removed; the deposition must thus have taken place at considerable depth, with a rock temperature at least approaching 100° F. Any ascending water at this depth must have had a still higher temperature.

The alteration of the country rock is confined to a relatively narrow zone on each side of the vein, and gradually diminishes in intensity with increasing distance from the vein. This would certainly tend to show that the vein-forming solutions did not penetrate whole rock masses, but that they were confined to the paths prescribed for them by the fissures.

In Grass Valley there is a series of fissures of slightly later age cutting the quartz veins. These fissures, called "crossings," are to a great extent open highways for the atmospheric waters which have been circulating on them for untold ages and still have not been able to fill them with quartz or ore. The existence of this open-fissure system is one of the strongest possible proofs against the theory of lateral secretion in its narrower sense, implying a leaching from the country rock by atmospheric waters and deposition of ore by these waters in the fissures.

ORIGIN OF THE METALS AND GANGUE.

Admitting that the vein-forming waters were ascending thermal waters, the next question is, whence they derived their load of dissolved substances. The above discussion shows that the leaching by surface waters of the country rock is wholly inadequate to explain the vein phenomena. But it might be supposed that the contents of the veins—especially the gold and metallic minerals—have been extracted from the immediately surrounding rocks by the intense chemical action which is admitted to have taken place. This explanation is, in the first place, wholly inadequate quantitatively, for it is inconceivable that the relatively narrow zone in which the microscope shows that alteration has taken place should have furnished the large quantity of gold occurring on the veins. In the second place, the occurrence of practically identical vein fillings in a dozen rocks of the most widely differing character and age constitutes the strongest argument that can be adduced against the immediate derivation of the gold from these rocks. Other facts, such as the change in character of the filling in one and the same rock, point the same way.

According to the analyses, barium is found in notable quantities in the granodiorite, and barite should, according to the theory of lateral secretion, be found on the veins. Yet no specimen of this mineral has been collected from any of the veins, and, indeed, in the altered country rock that has been exposed to the action of the solutions the small percentage of barium is only slightly decreased.

In the basic augite rocks grains of copper pyrites are of rather common occurrence, and copper has been found analytically in two of the examined diabases. According to the theory of lateral secretion, copper pyrites should be abundant on the veins, yet in many of the veins in diabase chalcopyrite forms an insignificant part of the sulphurets or is practically absent. Two substances have, however, unquestionably been abstracted from the altered country rock by the solutions, namely, silica and sodium; possibly also other metals, but the latter in quantities which are so small as to be of no significance for the vein filling.

RARER METALS IN THE ROCKS.

It is quite possible that one or several of the rocks of the district may contain gold and silver or other heavy metals, and it is to be regretted that circumstances prevented the contemplated extensive series of tests. The occurrence of copper in two diabasic rocks from Grass Valley has already been referred to. Mr. George Steiger carefully examined, without any results, the granodiorite from Shurtleff's barn, one-half of a mile ESE. of the post-office, Nevada City (also analyzed, see Chapter X), for rarer metals, using a solution of 10 grams in aqua regia. A coarse-grained diabasic rock with fresh augite from the area south of Banner Hill was also examined in a similar way, with no results (59 N.C.).

A series of assays was carefully made by Mr. C. Whitehead, the assayer of the mint, with a view of finding minute traces of gold and silver. The granodiorite from Shurtleff's barn, Nevada City, gave no results. The granodiorite from Kate Hayes Hill, Grass Valley (49 G. V.), contained no gold, but 0.2 ounce of silver per ton. From appearances this was thought to be a very fresh rock, but the analysis shows a little pyrite, and the microscope shows a decided beginning of sericitic and chloritic alteration. Fresh diabase from south of Banner Hill (59 N. C.) gave no result; nor did a uralitic diabase, containing a trace of copper and much pyrite, from Leeman's ranch, Diamond Ravine, west slope of Osborne Hill, Grass Valley. A somewhat chloritic diabase from the seventh level of the Idaho shaft, 20 feet from the vein, gave no results. A breccia of argillite and porphyrite with abundant pyrrhotite, occurring on the lower road just east of the little gulch 1,700 feet south of Banner Hill, was next assayed. It has been indicated above that this pyrrhotite is not due to the vein-forming agencies, but is of earlier date and contemporaneous with the dynamo-metamorphism of the Jurassic or Cretaceous igneous rocks, which, again, took place before the granitic intrusions. Pieces rich in pyrrhotite were selected, and a trace of gold and 0.4 ounce of silver to the ton were obtained. The locality is, however, nearly in the continuation of the veins appearing just west of the summit of Banner Hill, and it would be difficult to assert positively that it did not contain small seams and fissures along which the vein-forming solution could have penetrated, so that, while suggestive, the result is not decisive. The main difficulty in the way of these tests is to obtain satisfactory material, positively free from joints and seams, by which the auriferous solution could have been introduced.[1] A local segregation of pyrite, epidote, magnetite, and chabazite from the Star tunnel in diabase above the Omaha mine, which certainly also belongs to the phenomena of general metamorphism and not to those of the gold-quartz veins, was assayed (24 G. V.); it contains no gold, but 1.20 ounces of silver. It would be of interest to examine the quartzose sandstones of Grass Valley for gold, but here, again, the difficulty of obtaining satisfactory material is great.

Though fragmentary and unsatisfactory, these results seem to indicate that traces of gold are not common in the rocks of the district. They further seem to indicate that wherever anything is found it is silver and not gold which predominates, while the reverse is true of the veins. It is believed that both silver and gold occur in very minute quantities in nearly all rocks of the districts, and that the pyrite and pyrrhotite developed in them by metamorphic processes, not hydrothermal in character, contain this silver and gold as a concentration. But it is not believed that the bulk of the metals of the veins is derived

[1] Pyritiferous amphibolites from the Ophir district, Placer County, gave similar results; for instance, 0.010 ounce Au and 0.240 ounce Ag: Fourteenth Ann. Rept. U. S. Geol. Survey, Part II, 1894, p. 263. It is believed that the pyrites in these rocks are due, not to vein formation, but to the general metamorphism preceding it.

from the rocks immediately adjoining the vein. Their origin must still be left an open question; but the probability is strong that they were dissolved from the more deep-seated parts of the granodiorite, which appears to form the foundation of the Sierra Nevada, and brought to the surface by the thermal waters, the whole process being the closing chapter, the last manifestation, of the abyssal granitic intrusions. In other parts of the world a probable connection has been established between acid rocks, such as granites, quartz-porphyries, and quartz-diorites, with the gold veins; and metallic, unquestionably primary gold, has been found in such rocks.

Further questions not yet solved are, first, the remarkable dependence of the gold-quartz vein on the extent of the metamorphic series, shown in the paper on the "Gold-quartz veins of California;" and second, why, if derived from deep-seated rocks, fluor and bor compounds should be so universally absent.

These views do not imply a derivation from extreme depths or from the hypothetical "barysphere." The thermal waters rising on the veins were doubtless surface waters from the higher portions of the range, which penetrated to a considerable depth before reaching the surface again, but a few thousand meters would probably be the greatest depths attained by them. It should be borne in mind, however, how extremely unsatisfactory our knowledge of the circulation of deep-seated waters is.

SOLUBILITY OF THE GANGUE MINERALS.

According to Fuchs,[1] amorphous freshly prepared silica is soluble in water to the extent of 130 grams per ton. The natural siliceous waters show, however, a far greater solubility; the Iceland geysers contain up to 606 grams per ton; Steamboat Springs, Nevada, 306, and the Yellowstone Park geysers up to 580. The silica in the latter is not precipitated by cooling, even to freezing point, when not exceeding 400 grams per ton, and, according to F. A. Gooch,[2] it is probable that the compound is not contained as alkaline silicates, but as free hydrated silica. Saturating the waters with H_2S or CO_2 did not produce precipitation.

Calcic carbonate is slightly soluble in pure water at ordinary temperature (200 to 360 grams per ton of water, Doelter). In water saturated with carbon dioxide the neutral carbonate dissolves under formation of bicarbonate at the rate of 0.88 gram to the liter, or practically 880 grams to the ton.[3] With a small percentage of sodic or magnesic sulphate the capacity for solution is nearly doubled.[4]

[1] Doelter, Chemische Mineralogie, Leipzig, 1890, p. 189.
[2] Formation of travertine, etc., W. H. Weed: Ninth Ann. Rept. U. S. Geol. Survey, 1889, p. 655.
[3] Roscoe and Schorlemmer, Vol. II, p. 208.
[4] T. Sterry Hunt, Am. Jour. Sci., 2d ser., Vol. XLII, p. 50.

RELATION OF SOLUBILITY TO INCREASED PRESSURE AND TEMPERATURE.

It is a widely accepted view that in general the decrease of pressure and temperature forms an important factor in the formation of mineral deposits by ascending hot springs. In view of this, it may be profitable to inquire how, as far as we know, the solutions of different substances are influenced by the increase of pressure and temperature.

It is proper to draw attention at the outset to the fact that the question is extremely complicated, for the presence of other substances, as a rule, affects the solubility of any given salt; so that the rules obtained from simple solutions of certain compounds may not be applicable at all for solutions of the same in mineral waters.

Pressure certainly affects the solubility of many substances, but the result may be either an increase or a decrease. The investigation of Braun[1] shows that the rate of increase (positive or negative) is a function of the pressure, temperature, heat of solution, and change of volume taking place in the solution. If contraction takes place, which is the less common case, there is in general a decrease of solubility.

Regarding silica, there are apparently no data available; deposition taking place from highly saturated solutions may be due to loss either of heat or of pressure.

In the case of carbonates, and especially calcite, pressure is said to increase the solubility in water saturated with CO_2, but only up to a certain degree, the maximum amount that can be dissolved being 3,000 grams per ton.[2] Sodic chloride shows only a very slight increase in solubility by increasing pressure. Sodium sulphate, common in the mineral waters, shows a distinct decrease in solubility.

The influence of temperature has been more extensively studied. It may be said that up to about 100° C. there is in general an increase in solubility, but recent experiments seem to prove that for many substances there is, in fact, after a certain point has been passed, a distinct decrease.

No results are known in regard to silica. Calcic carbonate shows a slight increase in solubility in pure boiling water, one part being soluble in 10800 cold and 8875 parts of boiling water (Fresenius).

On the other hand, Engel and Ville[3] have shown that increase of temperature decreases the solubility of carbonates, especially magnesian carbonate. Sodium sulphate shows, according to Gay-Lussac and others,[4] an increase up to 35°, then a sudden decrease and nearly constant solubility up to 100°.

The other sulphates show similar relations, according to Etard.[5] Sodic, calcic, and ferrous sulphates, for instance, increase in solubility up to between 60° and 120°, from which a gradual decrease begins,

[1] Ostwald, Allgemeine Chemie, p. 1046.
[2] Roscoe and Schorlemmer, Vol. II, p. 206.
[3] Compte Rendu., Vol. XCIII, p. 340.
[4] Ostwald, Allgemeine Chemie, p. 1048.
[5] Ostwald, Allgemeine Chemie, p. 1052.

potassic sulphate alone increasing steadily up to 200°. Sodic chloride increases very slowly in solubility up to 100°. Applying the formulas of vapor-tension to the problem of solubility, Le Chatelier[1] arrives at the result that, in general, the curve representing the solubility will rise up to a certain limit at 100° C. or 200° C., and then gradually sink again.

Assuming a mineral water emerging at the surface with a temperature near the boiling point and a gradually rising pressure and temperature down to a depth of several thousand feet, it becomes clear that we are not in the least justified in assuming a gradual and indefinitely extended increased solubility in depth, or, reversed, that conditions for deposition will gradually become more favorable as upper levels are reached. It is in fact more probable that for temperatures rising high above 100° C. and under increasing pressures there will be a decrease in the dissolving power of the waters, at least as far as the principal constituents of the water are concerned. In all probability the quartz veins here described were deposited from solutions at great depth below the surface, under strong pressure and at temperatures ranging perhaps from 100° C. up to 250° C. It is true, and the fact agrees with results previously stated, that at the mouth of the crevice deposits of many substances are formed by suddenly diminishing temperature, but it does not at all follow that a diminution from 200° C. to 100° C. will produce a result similar to that of cooling from 100° to 0°. Besides, the precipitation at the surface is very largely caused by the oxidizing influence of the air, escape of carbon dioxide, evaporation, reduction by organic matter, and algous growth.

SYNTHESIS OF GANGUE MINERALS.

Quartz has been reproduced by Chroustchoff, Doelter, Senarmont, and others from alkaline solutions of silica or by recrystallizing gelatinous silica. According to Doelter,[2] quartz can not be reproduced from aqueous solutions at a temperature below 250° C. The facts hardly appear to bear out this assertion. At Steamboat Springs there are vast masses of siliceous sinter which are distinct surface accumulations and scarcely can have been found at a temperature above 100° C.—more probably below. Yet this sinter consists of a mixture of prevailing opal and chalcedonite, with smaller masses of finely granular quartz, often with crystallographic outlines. Small quartz crystals are found in the silicified wood of the auriferous gravels, where the temperature can hardly have been very high at any time.

Opal or cryptocrystalline silica may be deposited at considerable depths, as its occurrence in several deep mines of Grass Valley indi-

[1] Ostwald, Allgemeine Chemie., p. 1067.
[2] Loc. cit., p. 154.

cates. Doelter's experiment on the solubility of gold, recorded below, indicates the same fact.

The different carbonate minerals may easily be reproduced at ordinary as well as at higher temperatures up to 500° C. (Friedel).

SOLUBILITY OF GOLD.

Considering only the solvents common in mineral waters, it is found that gold is attacked by many of them. Egleston found a slight solubility of gold in sodic and potassic chloride, as well as in many other salts of less importance for the present purpose.[1] Doelter has lately found that gold is soluble in a 10 per cent solution of sodic carbonate heated forty-seven days in closed iron tubes at 200° to 250° C.; also in a solution of 125 c. c. water containing carbonic acid as well as 8 per cent sodic carbonate and 3 per cent sodic silicate. In this latter experiment the gold was dissolved at the rate of 21.5 grams per metric ton of water. In the first experiment 1.22 per cent of the gold used was dissolved, which, under the assumption that a similar quantity of water was used (not expressly stated in the original), would give a solution of 42.4 grams per metric ton of water. These figures correspond to a value of $13.39 and $26.28 per ton of water.

An extremely interesting feature of the last experiment was that upon opening the tube a few minute crystals of gold were found, which in all probability were newly formed, and further, that small crystal aggregations of quartz had formed, as well as a large mass of hydrous silicic acid in globular concretions. In this as well as the following experiment on sulphides the heating was carried on only during the day, so that the interruption of the process may have had something to do with the deposition of the newly formed substances.

Liversidge[2] also found that gold was dissolved by sodic silicate, but it is doubtful whether this reaction is of much importance, as it is not at all likely that the alkaline silicates can exist in the presence of carbon dioxide.

Previously to Professor Doelter's experiment Dr. G. F. Becker[3] had found that gold is relatively easily soluble in sodic sulphide (Na_2S), a solution containing 843 parts of the latter dissolving 1 part of gold at ordinary temperature. Gold also, according to Becker, dissolves at ordinary temperature in sodic sulphydrate and in solutions of sodic carbonate partially saturated with sulphydric acid.

SOLUBILITY OF SULPHIDE MINERALS.

Doelter found that pyrite, galena, antimonite, sphalerite, chalcopyrite (in part), arsenopyrite, and bournonite are to some extent soluble in pure water, when heated for almost four weeks in glass tubes to a

[1] Trans. Am. Inst. Min. Eng., 1880, Vol. VIII, p. 455.
[2] Proc. Royal Soc. New South Wales, Vol. XXVII, 1893, p. 303.
[3] Mon. U. S. Geol. Survey, Vol. XIII, 1888, p. 433.

temperature of 80° C. About one-eighth or one-tenth of the remaining undissolved, finely powdered mineral was in addition usually found to be recrystallized. Pyrite was soluble at the rate of 1,000 grams per ton of solution, or 0.10 per cent. The solution of galena contained 270 grams of PbS per ton.[1]

According to the same authority, galena and pyrite are also to some extent attacked by water containing carbon dioxide.

Becker[2] found that pyrite is soluble in cold solutions of sodium sulphide. Ten cubic cm. of solution containing 1.0955 grams of sodium sulphide dissolved 0.6 gram of pyrite, the solution thus containing about 60 grams of pyrite per ton, or 0.006 per cent. Pyrite is also soluble in hot sodic sulphydrate, but not in cold, and is relatively easily soluble in cold and hot solutions of sodium carbonate partly saturated with hydrogen sulphide.

Similar results were obtained with the sulphides of mercury, copper, zinc, and, of course, arsenic and antimony. The sulphides of lead and silver could not be brought in solution, the former not even when heated to 100° C. in closed tube.

Doelter's[3] later experiments show that pyrite, galena, zincblende, arsenopyrite, chalcopyrite, and bournonite are all soluble in sodic sulphide by treating the finely powdered minerals for twenty-four days of twelve hours at a temperature of 80° C. in glass tubes. Quantity of mineral used, about 1 gram; quantity of liquid, about 40 to 50 c. c. Of the pyrite, 10.6 per cent was dissolved, corresponding to an approximate content of 0.2 per cent of pyrite in the solution. Galena is even more soluble. In comparing these large amounts with Becker's results it would thus seem that time is a very important factor in the solution of these minerals. In regard to the solubility of tellurium compounds, which evidently have a close relationship with the gold, there are no data available.

EFFECTS OF INCREASED PRESSURE AND TEMPERATURE

In regard to the influence of heat and pressure upon the solubility of gold and sulphides, there are but few definite data available, and, in fact, the problem is much more difficult than that offered by the ordinary easily soluble salts. The experiments by Becker and Doelter indicate that heat, and perhaps also pressure, increases the solubility, but how far this increase extends is almost entirely unknown. It is not unreasonable to suppose that, as with other salts, this increase is not indefinite, but reaches a maximum and then again declines.

---

[1] Tschermaks mineral Mittheil. 1890, Vol. II, p. 319.
[2] Loc. cit., p. 432.
[3] Loc. cit., p. 323.

SYNTHESIS OF THE SULPHIDES.

In discussing the solubility of the metallic minerals, especially the sulphides, it has been tacitly assumed that they might have been formed simply by separating out from their solvents by changes affecting the latter. This is certainly not the only way in which they could have been formed in the veins, as is proved by the relative ease with which most of them can be formed synthetically in the wet way, chiefly by the action of sodic or hydric sulphides on different salts. Pyrite, galena, chalcopyrite, argentite, tetrahedite, bournonite, and arsenopyrite have been obtained by Senarmont and Doelter in this manner. Pyrrhotite requires for its formation the presence of an atmosphere of carbon dioxide or of reducing organic substances, entirely preventing the change from ferrous to ferric salts.

This is interesting in view of its extensive presence in metamorphosed argillites (Federal Loan), and in view of its entire absence from the veins (excepting a seam of abnormal composition in the Crown Point mine). Even the veins in argillite (Federal Loan) do not carry it; the pyrrhotite of the metamorphic argillite, close to the vein, is also, remarkably enough, converted into pyrite.

Marcasite has not yet been artificially produced; nor has zincblende; wurtzite, the rhombic modification, however, Doelter succeeded in obtaining.

The reaction by which the oxides of iron or other iron salts are converted to pyrite by the action of hydric sulphide or sodic sulphide is evidently of great importance. This reaction was shown by Dr. G. F. Becker to have taken place to great extent in the altered country rocks of the Comstock lode, the pyrite being principally, apparently, derived from the ferrous silicates; it was experimentally verified by Doelter[1] in case of oxides and carbonate of iron. It is clear that the ferro-magnesian silicates and the magnetite in the wall rocks have furnished the greater part if not all of the iron for the pyrite in the altered rocks, while it is equally certain that comparatively little iron has been carried from the country rock in the vein.

PRECIPITATION OF THE GOLD.

There are many experiments recorded as to reactions by which gold could have been precipitated from its solutions.[2] Ferrous sulphate is one agent. This is, however, too complete and sudden a reaction to be supposed to have a general importance in the formation of the gold veins. Precipitation by organic matter in the wall rocks is another, and the black slates along the Mother lode have been extensively quoted as a suitable cause for the deposition of gold. There is reason to believe that the importance of this reaction has been greatly overestimated, if

[1] Chemische Mineralogie, p. 148.
[2] A. Liversidge, Proc. Royal Soc. New South Wales, Vol. XXVII, 1893, p. 303.

indeed it is of any importance at all. The carbonaceous argillite of the Nevada City and Banner Hill districts offers an excellent criterion, and it does not appear to have the least influence on the tenor of the quartz in that rock, while other veins wholly in massive rocks and far away from any carbonaceous matter may be much richer than those in the slate. Certain experiments by Wilkinson (1866), Cosmo Newbery, Skey, and Liversidge[1] show that pyrite and also nearly all other sulphide minerals, including galena and arsenopyrite, will precipitate gold completely from solutions of auric chloride of varying concentration. This reaction is probably of considerable importance, as it explains the strong percentage of gold usually contained in the sulphurets in a state of minute dissemination.

Many other proposed reactions might be cited, but they appear of questionable value in speculating on the particular combination in which the gold is contained in the water. According to the views of modern chemistry, watery solutions of salts, even when only moderately diluted, contain the solids in a state of dissociation. Salts of gold could probably not exist as such in the mineral waters.

MODE OF DEPOSITION.

In discussing the mode and cause of deposition, it must be acknowledged that we have to deal with data only imperfectly known, and that the conclusions drawn from them are not yet more than a theory. Bearing in mind all the facts adduced, it seems certain, however, that the deposition has been effected by thermal water containing carbonates, silica, and sulphureted hydrogen or sodium sulphide, and containing also measurable quantities of gold and metallic sulphides. It would carry us too far to discuss the origin of this water and the source of its constituents. On the whole, the views of Daubrée and Posepny seem the most reasonable explanation. In the words of the latter, "The ground water descends by capillarity through the rock interstices over large areas, to mount again through open channels at a few points."[2]

During their long descent to heated regions the waters had ample opportunity to dissolve the substances contained in the rocks, and in this case probably obtained their gold and other heavy metals from the granodiorite at great depth.

It must be confessed, however, that the large quantity of carbon dioxide and sulphureted hydrogen carried by many thermal waters is extremely difficult of explanation. During its downward course the waters can not have taken up CO_2; on the contrary, descending surface waters in a short time are deprived of their CO_2 by the forming of carbonates. It is not probable that extensive bodies of limestone occur in depth in this vicinity.

It has been shown that pre-Neocene erosion had removed a great

[1] A. Liversidge, Proc. Royal Soc. New South Wales, Vol. XXVII, 1893, p. 303.
[2] Genesis of ore deposits: Trans. Am. Inst. Min. Eng., Vol. XXIII, 1893, p. 221.

deal, probably a couple of thousand feet at least, of the upper parts of the gold veins, and that the levels at which mining is now carried on were probably from 2,000 feet to 5,000 feet below the original apex. Within this interval there is certainly no change in the quality of the ore (excepting decomposition above water level), nor can it be said that a change in quantity has been definitely proved. Within the limits of explorations by deep mining no definite progressive change in the character of the ore or of the altered country rock has been found, such as would undoubtedly exist if the cause of deposition were decreasing pressure and temperature. From this, as well as from the results of the investigations of solubility of the different substances, it may reasonably be concluded that an undue importance has been attached to the rather seductive phrase "deposition by decreasing pressure and temperature," though it is not to be denied that the deposition may be in part a function of these variables.

The metasomatic action on the wall rocks is undoubtedly of great importance for the deposition. The facts stated several times before show that there is but very little free gold in the altered wall rock and very little gold in its sulphurets, while the main amount of the gold and the auriferous sulphides are contained in the quartz filling the fissure.

It may be possible to consider the walls as forming a septum permeable only for a part of the solution, according to the osmatic laws,[1] especially for the substances which act chemically upon the minerals of the rocks. The latter in general are shown to be permeable for the carbon dioxide and alkaline carbonates; also for carbonate of calcium; further, for hydrogen sulphide or sodic sulphide, and for arsenic sulphide. On the other hand, they are less permeable for silica and gold, and almost entirely impermeable for the other metallic sulphides. This suggests the possibility that the hydrated silica is contained in the water in colloidal solution. Sulphide of gold in colloidal solution, impermeable for the ordinary parchment membranes used in the dialyzer, has been prepared by Dr. E. A. Schneider.[2] It might possibly have existed in the waters, though the probability is that it would be decomposed by some of the constituents of the mineral waters. It is also known that the sulphides of the heavy metals in general can form colloidal solutions.[3] However, the properties of colloidal solutions are only imperfectly known, and it is doubtful whether crystallization could take place in such solutions.

By metasomatic processes the wall rocks absorb carbon dioxide, potassium, sulphur and lime from the vein solutions. On the other hand, there has been a steady acquisition of sodium (probably as carbonate) and of silica, abstracted from the wall rocks. The result of

[1] Dr. G. F. Becker first introduced this conception applied to the mineral deposits, and it promises to be of great importance for the discussion of their genesis. See "Quicksilver ore deposits," in Mineral Resources U. S. 1892, p. 21.

[2] Bull. U. S. Geol. Survey No. 90, 1892, p. 56.

[3] Bull. Soc. chimique, vol. 48, 1887, p. 165.

the whole process would probably be a concentration of the vein solutions and progressive accumulation of silica. As far as the chief constituents are concerned, the vein solutions were very likely highly concentrated. The deposition of silica was probably partly caused by an unbalancing of the delicately adjusted conditions in a concentrated solution of different compounds by the new material from the wall rock, and partly by varying conditions of temperature and pressure.

The metallic sulphides and the gold carried by the silica were probably to a great extent precipitated mechanically by the crystallizing quartz. The intimate connection of the gold with the sulphides was very likely caused by the experimentally proved tendency of gold solutions to be precipitated by particles of sulphides.

The causes to which the occurrence, form, and direction of the ore shoots are due are very obscure, and to extend the discussion to them would be to go farther in the realms of hypothesis than is here desirable.

CHAPTER XIV.

DETAILED DESCRIPTIONS.

BANNER HILL DISTRICT.

VEINS OF THE DEER CREEK BASIN AND WILLOW VALLEY.

General features.—These veins have in general an east-west strike and flat medium northerly or southerly dip. The ores are frequently of high grade and the fissures narrow. The gold is associated with much silver, and there is a considerable amount of sulphurets. A few veins having a north-south strike and flat westerly dip intersect the

FIG. 10.—Sheeted zone in granodiorite, Deer Creek. Bellefountain mine.

prevailing system. The east-west veins are in closest genetical connection with a system of joints or a sheeting of the country rock; this sheeting begins to show very strongly a little beyond the Deadwood mine, and may be seen to best advantage all along the rocky canyon of Deer Creek. Fig. 10 illustrates this structure; granodiorite is divided in benches or sheets from 1 to 4 feet thick and dipping north at slight

angles. Opposite the Bellefountain mine the strike is N. 78° E. and the dip 30° N.; at the Lecompton mine the strike is east-west and the dip 30° N. On the Federal Loan road opposite the big bend, 500 feet west of the contact, N. 68½° E. and 35° N. was noted; here the sheeting seems most intense. In a width of 1 foot six or more minute seams were seen, dipping as stated, and each marked by a slight bleaching of the granodiorite and by a fine string of iron pyrite. The normal granodiorite does not contain any pyrite. This sheeting continues unbroken across the contact, but the direction swings a little more to the northeast and the dip becomes decidedly steeper, up to 68°. Besides the joints dipping north, another set now begins to appear, about parallel to the first in strike, but dipping south. In a fresh exposure of black, hard metamorphic rock on the ditch 2,000 feet east-southeast of the Federal Loan, the following directions were noted, the sheets being about 6 inches thick: (1) Strike N. 58° E., dip 70° N., and (2) strike N. 68° E., dip 60° S. The displacement which has taken place along these joint planes is probably in most cases very slight. Ascending waters have formed the most prominent veins along those fissures in this joint system which offered the easiest channel for their passage. There is always a strong possibility of finding veins parallel to and a short distance away from those exploited, and cross-cutting should consequently not be neglected in working the deposits in this vicinity.

The Federal Loan vein.—This is an old location, worked many years ago, but not opened on a larger scale until 1890; it has at present a 10-stamp mill, and the total output is stated to be $175,000.[1] The mine is developed by an incline shaft, following the vein down for a distance of 800 feet, and by drifts extending from 100 to 400 feet on each side. The mine is only a few hundred feet east of the granodiorite contact, and the country rock is that black or dark-brown, fine-grained, massive, siliceous argillite described in Chapter V. It is somewhat influenced by contact-metamorphic action, which has given it a slightly coarser texture and browner color, the latter caused by the development of biotite or brown mica. Dikes of coarse, dark diorite are met in the drifts of the mine. Pyrrhotite is distributed throughout the country rock in minute grains. The vein, which crops only near the shaft, strikes somewhat north of east and dips south at an angle of 45°. It is very irregular in width, sometimes showing several feet of massive quartz, then again closing down to a seam, or also frequently breaking up in a mass of stringers, which may be mined and milled as a whole on account of the gold contained in them. The wall rock itself contains but little gold.[2] The rock in the immediate vicinity of the vein is irregularly altered to a pale grayish material, often cut by small calcite veins, and containing much finely disseminated pyrite and arsenopyrite. This rock is examined more in detail in Chapter XI. The

[1] Nevada County Mining Review.

[2] Cf. Eleventh Rept. State Mineralogist, p. 290.

hanging wall of the vein is not well defined, but the foot wall continues unbroken and distinct. Numerous seams dipping north at various angles, but carrying no quartz, are noted, as illustrated on fig. 11. The mineral spring on the fourth level is described in Chapter IX. The filling of the vein consists of the usual milky-white quartz, occasionally containing grains of calcite. Fragments of the country rock, sharp and angular, though converted into carbonates and sericite, are very frequent in the quartz, and around these fragments the sulphurets often cluster, as illustrated in Pl. VII, fig. *b*. The ore contains the large amount of 6 per cent of sulphurets, which have a very high percentage of arsenopyrite and are of medium grade, containing somewhat more gold than silver by weight. (For analysis of concentrates, see p. 127.)

Arsenopyrite and pyrite prevail, while galena, zincblende, and copper pyrites are very subordinate.

The ore shoots are somewhat irregular, but the best pay is found in a chimney in the vicinity of the shaft, dipping about 70° E. on the plane of the vein. The value of the ore is stated to be $15 per ton.[1] The gold is 675 fine.

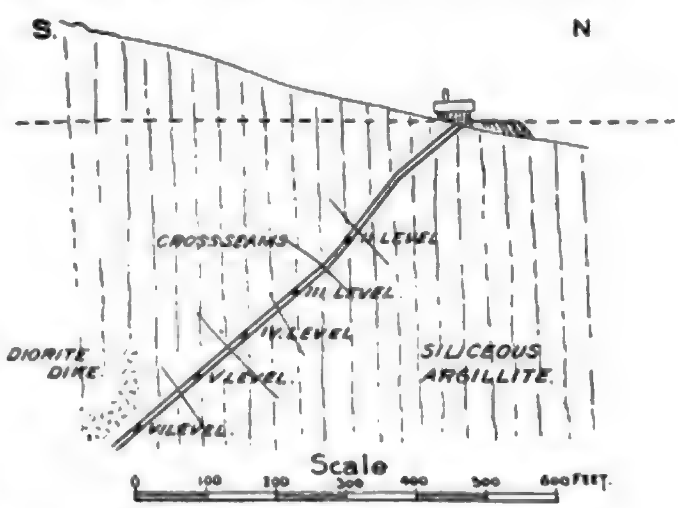


FIG. 11.—Vertical section along shaft, Federal Loan vein.

The Constitution and Levant claims.—The veins in the vicinity of the Federal Loan are not, as a rule, traceable on the surface for a long distance. North of it lie the claims just mentioned, located on veins belonging to the fissure system, dipping north. Some good ore is reported to have been found on the Constitution in former years, but the developments are slight. There appears to be in this claim a number of small parallel fissures. The country rock, which is a dense, siliceous argillite, is impregnated with iron pyrites along the veins. In the mint report of 1880 the vein is stated to be 1 foot thick, heavily sulphureted, and similar to the Lecompton.

The Lecompton vein.—The Lecompton is situated on the south side of Deer Creek, almost adjoining the Federal Loan. It was located in 1857, and up to 1863 the gross yield of the mine was $220,000. From 1863 to 1866 it was also a considerable producer; in 1867, however, the incline situated near the bed of Deer Creek was flooded by a freshet,

[1] Eleventh Rept. State Mineralogist.

the improvements destroyed, and no work has been done since then. It is credited in the mint reports of 1889 and 1890 with a production of respectively $5,350 and $900, which amounts probably came from remaining pillars of ore in the upper workings. The outcrop of the vein, owing to the flat dip, forms a curve high up on the slope; the ore in this part of the vein was decomposed and very rich, and has been extracted by means of numerous tunnels. Below the creek level the vein was opened by an incline near the east end of the claim, 275 feet long. There is also an incline 300 feet long near the western end. The vein is contained in granodiorite, strikes east-west, and dips 38° to 40° N. at the east incline. It is only from 4 to 8 inches wide; specimens show excellent comb structure. The gold near the surface had a fineness of only 650, while in the deeper workings it attained 750. The ore is stated to have contained arsenic and antimony, and was very rich, the upper parts of the vein averaging $40 per ton, and smaller lots running up to $400. According to the mint report of 1889, the bullion contained 416 per mille gold and 584 per mille silver.

Between the Lecompton and the Federal Loan lies the Lebel, a vein in granodiorite striking E. 23° S., dipping north, and opened by several short tunnels from the level of Deer Creek up on the side hill. The vein is up to 16 inches thick, of fair grade, and contains very abundant arsenopyrite.

On the north side of the creek, opposite the Lecompton, there are a great number of old slopes and tunnels run on narrow veins between the sheets of granodiorite.

The Bellefountain vein (formerly the Ebaugh).—This well-defined vein lies on the north side of Deer Creek, near the Lecompton. Located in 1857, it has been worked at intervals since then. It is opened only by tunnels run in from the steep slope of Deer Creek Canyon. The outcrop runs up the hill to an elevation of 270 feet above Deer Creek, and then crosses over into the Cyane claim; its direction is east-southeast, while its actual strike on a horizontal plane is east-northeast. The dip is 28° to 30° N. The vein averages 12 inches in width, and there are several small but rich ore shoots; no ore containing less than $24 is said to have been crushed.[1] This, as well as all adjoining veins, is in granodiorite. Close to the vein the fresh rock changes to a yellowish gray, soft mass of still clearly discernible granitic structure, consisting of sericite, some carbonate, residuary quartz, and abundant sharp cubical crystals of pyrite. (For description and analysis, see p. 149.)

Never Sweat and Omega veins.—These are veins parallel to the Bellefountain and located a few hundred feet farther north. The Never Sweat is opened by an incline 300 feet deep, has been worked only on a small scale, and is shut down at present. The information about it is obtained from Mr. J. Lyons. The country rock is a granodiorite with considerable hornblende, and decomposes to a reddish soil of great

[1] Nevada County Mining Review.

depth, on account of which the outcrop can not be readily traced on the surface. The vein is narrow, from 3 to 16 inches, and yields some very high grade ore, the value sometimes reaching $300. Generally similar to the Lecompton, the bullion contains some antimony and much silver, being only 750 fine. The strike is N. 73° E., and the dip at first 45° N. At a depth of 200 feet a cross vein is struck, belonging to the Federal Loan system of fractures, and, according to Mr. Lyons, the vein leaves the original fissure and continues on the one dipping south (fig. 12). This is of great interest as proving that the two vein systems are contemporaneous.

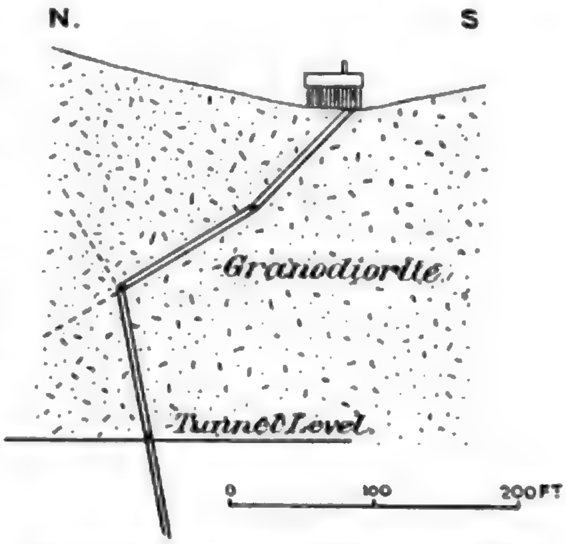


Fig. 12.—Vertical section along shaft, Never Sweat vein.

Near Willow Valley there are a considerable number of veins, none of which, however, have been worked very extensively.

The Montana vein.—This has been worked intermittently and has produced some good ore. It is developed by an incline shaft 400 feet long; strike northeast, dip 22° NW. The vein is from 6 to 8 inches wide, and can be traced for a considerable distance across the contact line. The ore, which is heavily sulphureted, forms two pay shoots pitching to the southwest on the plane of the vein, one on each side of the shaft and from 100 to 200 feet wide. In the claim are three more parallel ledges of less importance.

The Willow Valley vein (Tolbert).—Located in 1865, but little work has been done on this vein since 1867; 800 tons were taken out in 1866, yielding an average of $22 per ton.[1] It is developed by a 200-foot incline; the vein strikes northeast and dips 45° to the northwest; its width is from 1 to 4 feet. The country rock is granodiorite, the eastern end of the claim crossing the contact.

At the forks of the Washington and Scotts Flat roads is a small vein, striking N. 72° W. and dipping 70° N., on which a little work has been done.

The Franklin-Hussey vein.—Not much work has been done on this vein since 1884, when some very rich ore, going as high as $150 per ton, was produced. It is developed by an incline and drifts 230 feet long and extending 90 feet on each side. The strike is northeasterly and the dip 45° NW. The vein is in places from 1 to 2 feet wide.

[1] Bean's Directory.

The Buckeye vein.—This vein, which is opened by a 400-foot tunnel from Willow Valley Creek, has a northerly direction and an easterly dip of 45°, both unusual for this locality; it is inclosed in hornfels and is only a few hundred feet from the contact; the width is from 1 to 2 feet, and some good ore is reported from it. It can be traced from the creek northward until it disappears under the andesitic breccia.

The Deadwood vein.—This vein, which is located near the mouth of Willow Valley Creek on the north side of Deer Creek, has been a considerable producer at various times since 1856, but in the last ten years nothing has been done on it. A 10-stamp mill formerly existed on the property, and the total production is given by Mr. J. Lyons as about $300,000. The vein is opened by an incline shaft 500 feet long, a drain tunnel from Deer Creek, and several drifts extending principally southward of the shaft for 300 to 400 feet. The vein, which is in granodiorite, crops on the surface, where it is very flat, in a northeasterly direction. Its true direction, as shown by the incline and drifts, is N. 18° E., the dip being 25° W. The width is narrow, ranging from a mere seam to 18 inches. The ore is highly charged with sulphurets, carrying pyrites, galena, zincblende, and arsenopyrite, also containing some antimony. The tenor is high, sometimes reaching $100 to $200 per ton. Most of the ore has been extracted from the south side of the incline, while the northern side has been prospected but little. The bullion is 815 fine, which is more, it will be observed, than is usual in this part of the district. The croppings to the east of the incline, which over a large area lay extremely flat near the surface of the thoroughly decomposed granodiorite, have been extensively sluiced and even washed by the hydraulic process. According to Mr. Lyons, the vein is distinctly faulted on the tunnel level to an aggregate amount of 30 feet by four cross seams striking a trifle north of east and dipping 45° N. The vein was found to be thrown westward going north on the drift, which would indicate a reversed fault with relative upward movement of the hanging wall. The seams are comprised within 100 feet; in the lower workings the same seams were found a little closer together; without doubt they form the continuation of the Texas vein complex. The workings of the mine are not now accessible.

The Texas vein system.—About 1½ miles east of Nevada City, on the Willow Valley road, there is a strong system of at least four well-defined veins, named respectively the Creek, Wheal, New York, and Delaware (Red, White, and Blue). All strike about east-west and dip north at angles varying between 38° and 50°. The developments are slight, consisting chiefly of short tunnels from Mosquito and Deer creeks. The New York is opened by a 100-foot-deep incline (Texas mine). Some of the veins, especially the New York, are very heavy, 3 and 4 feet of solid quartz being met with; on the road a little east of the Texas mine the croppings are unusually strong; in the best pay shoots the ore from these veins runs from $8 to $40 and contains 4 per

cent or more of sulphurets. The Delaware continues far eastward over on the Murchie ground. These veins seem to form the starting point for the Willow Valley system, the originally strong fissures being replaced eastward by an extensive system of sheeting.

The Murchie veins.—This complex consists of two east-and-west veins, the Big Blue and the Alice Belle, as well as two north-and-south veins, the Lone Star and the Independence. The property has been worked at various times since 1861, the principal producer being the Big Blue; from 1878 to 1884 the mine was one of the largest producers in the district and had an 18-stamp mill; detailed statements of its production are found in the mint reports. From 1884 to 1894 it was shut down but has lately started again, probably with the expectation of using electric power. From 1878 to 1884, 38,000 tons were crushed, containing $587,000, or an average of $15 per ton, with 4 per cent of sulphurets, at an average cost of $1.60 for milling and $6 for mining per ton. The sulphurets are very rich, containing from $100 to $300 per ton (Mint Report, 1883). The Big Blue is almost perpendicular, dipping 85° N., which is unusual in these districts. The vein is often very wide, even up to 4 and 5 feet, and consists of white massive quartz, which besides free gold contains iron pyrites sprinkled through it; tellurides are also reported from the vein (p. 117). The principal ore shoots on the vein dip west and appear to follow the lines of intersection with the flat veins. A decomposed porphyritic rock found on the dump of the Independence is said to come from a dike following the Big Blue for some distance. It is described in Chapter III, p. 47, and appears to be a lamprophyric dike rock.

The Independence is also a heavy vein, sometimes 2 or 3 feet thick. According to Mr. Murchie it was at the line of intersection *cut off* by the Big Blue, the latter passing through it without faulting to any extent. The Lone Star vein can be traced up to the old placer diggings, where it intersects the Alice Belle. Some good ore is reported from the latter.

MINES OF THE LITTLE DEER CREEK BASIN.

General features.—Aside from a few veins in the lower part of the basin, there are two centers in this part of the district where the majority of the veins are clustered, namely, Canada Hill and Banner Hill. At the former place a large number of smaller veins are contained within the angle of the two strong fissures of the St. Louis and the Orleans (Glencoe) veins. These smaller veins belong to several systems, one striking north and south and dipping west, another with the same strike but dipping east; there are also flat veins dipping south, and other east-west veins with a steep dip. This great complex lies, as the map shows, near the granodiorite-slate contact, but the veins show no relation to the latter, frequently crossing it without being disturbed. Further, though individual veins show the greatest divergence as to

their contents and value, no influence on their character can be attributed to the different formations. In general, the mines in this vicinity are characterized by comparatively low-grade bullion, about 750 fine, much sulphurets, and especially much arsenopyrite and zincblende. A strong system of sheeting is developed parallel to the first-mentioned system of veins; the flat, thin benches of granodiorite dipping west are particularly well exposed along the Banner Hill road near Little Deer Creek; the sheets, from 6 inches to 2 feet thick, though as a rule parallel, sometimes show slight divergences in strike and dip. Small quartz seams are sometimes seen on the joints. The Banner Hill group of veins are in the main parallel fissures with an easterly dip of about 45°; they are partly in the sedimentary area, partly in the granodiorite, without very marked differences in vein filling and value; as a rule they contain much silver, and also a considerable amount of sulphurets. A sheeting of the country rock is frequently noticeable, the sheets dipping either east or west.

The Caledonia vein.—This vein is traceable on the surface for several hundred feet on the slope north of Little Deer Creek. The strike is a trifle north of east, the dip nearly vertical. It is opened by several old shafts and a tunnel from Little Deer Creek, 1,200 feet long, but no work has been done in recent years. The vein is said to be very wide and to contain low-grade ore. All above the tunnel level is stoped out; the ore consists of massive quartz with abundant pyrite. A considerable quantity of water, tasting strongly of iron and depositing a brown ocher, issues from the tunnel.

The Kingsbury veins.—South of the Caledonia, on the north side of Little Deer Creek, are two or three strong parallel veins, situated on the Kingsbury location. They have been opened only by short tunnels and prospect shafts; the dip is about 80° N., and the width of the solid quartz is from 1 to 3 feet. The Alice Belle is possibly an eastern extension of these veins.

The Lincoln vein, just south of Little Deer Creek, is a parallel vein in which a little work has been done, and which in the mint report is credited with a small production for the years 1889 to 1891.

The St. Louis vein.—The remarkably strong and straight fissure of the St. Louis vein can be traced for about 7,000 feet from the western limit of the Banner Hill sheet, on McCormick's ground, up to a place where it disappears under the andesitic breccia. Its direction is east-northeast and the dip 70° to 80° to the north. The ore throughout is very low grade, and the developments on it are slight, mainly confined to a few tunnels. At the eastern end its decomposed croppings have been extensively sluiced; on a claim called the Santa Rosa a crosscut is now being driven to intersect the vein. The Alpine tunnel was driven on this vein a distance of 400 feet in 1893, starting from the east bank of Little Deer Creek. On the opposite or Canada Hill side, there is also a tunnel on it several hundred feet long and serving as drain

tunnel for the Charonnat mine. The width of the vein is given as up to 12 feet, but this doubtless includes the altered country rock. In the Alpine tunnel good exposures were noted. For the first 150 feet the granodiorite is much decomposed; farther in the quartz vein is from 1 to 4 feet thick and charged with a small quantity of pyrite and zincblende; both walls are well defined and consist of somewhat decomposed granodiorite. A dike of extremely decomposed diorite-porphyrite (a lamprophyric dike rock; for description, see p. 47) 2 to 3 feet wide appears in the hanging wall, 300 feet in, and forms the sharply defined wall of the 2-foot vein of solid quartz. Near the breast a seam was observed, dipping west and parallel to the sheeting previously noted; it cut across the quartz vein and showed a horizontal striation. Toward the west the vein splits up into three or four parts, and is well exposed on R. Sharpe's and McCormick's ground, where the shallow covering of rich alluvium has been sluiced off.

The Glencoe-Gracie (Orleans) vein.—This vein, one of the longest in the district, being traceable for nearly 3 miles, has been known since the earliest times of mining in this vicinity, but can show no product commensurate with its size, although it has been worked at several places. The strike is remarkably constant, being a little north of west. The dip is equally so, being 70° to 80° S. The vein throughout is in slate, which near the granite contact becomes more crystalline and schistose, and it cuts distinctly the dip of the schistosity. It first appears on the Mayflower ground, where it is called the Alaska and is opened by small prospect shafts, showing some good quartz heavily charged with sulphurets. Continuing westward, it is known as the Glencoe on R. Sharpe's ground. Here it is developed by a 98-foot deep shaft and a 500-foot drain tunnel, above which the ore is stoped out. At this pay shoot the vein is stated to be 4 feet thick, contains abundant sulphurets, and is of medium grade. Steps were taken to reopen this mine in 1894. The next claim westward is the Gracie; a 54-foot shaft on this property shows 1 to 2 feet of quartz in a fissured zone 6 to 7 feet wide.

The westerly claims on this vein are described on p. 193. Between the St. Louis and the Glencoe a perfect network of small veins exists, the more important of which are indicated on the map. South of the Glencoe are the Hickson veins, opened by small shafts and a short tunnel, and said to have yielded some rich ore. Mr. Sharpe states that there are three veins within 50 feet, the outer two dipping toward the one in the middle, which is perpendicular. The Enterprise contains low-grade ore, and has not been worked since 1859.

To the north of the Glencoe there is, among others, a series of very flat veins with a southerly dip of from 0° to 20°. It is possible that the different croppings may represent one and the same vein, continuous from McCormick's ground to the Mayflower at Canada Hill. On the east the flat vein was found by Mr. McCormick in sluicing and

hydraulicking the shallow placers and decomposed rock on the slope on both sides of the Gracie vein. It is here in slate, narrow, but rich, and sometimes so flat as to be almost horizontal. In one place it even made a roll, so that part of it actually dipped north. It is stated to have joined the Gracie vein without cutting the latter. Another flat ledge is found in granodiorite on Sharpe's ground near the contact and to the east of the Banner Hill road, and, finally, similar veins are strongly developed on the Mayflower ground.

THE MAYFLOWER COMPLEX.

At least eight well-defined veins are found on the Mayflower property south of Canada Hill. The more important veins were located over twenty-five years ago, but until ten years ago had not been worked except superficially. A 4-stamp mill crushed rock from the Beckman vein in 1893, but in 1895 a new 20-stamp mill was erected. The developments in 1893 consisted of an incline and several tunnels on the Beckman and the Mayflower veins. The Beckman has been worked for 1,500 feet along the croppings and 300 feet along the dip, but the greatest perpendicular depth attained is only 75 feet. On the Grant a 300-foot incline has been sunk. The country rock throughout is a black, very imperfectly schistose argillite, grading into hornfels near the contact. Only the Grant vein cuts across the contact into the granodiorite. Strong jointing is shown at the Beckman incline, one system dipping 60° west, while the other dips 30° to the east.

The three perpendicular east-west veins, the Butterfly, North Star, and Big Blue, while strong and well defined, carry low-grade ore and have been but little exploited, and the same is true of the Floyd vein. The Grant vein is more productive and contains near the contact, as well as northward in the adjoining Canada Hill ground, some good pay shoots; 555 tons, averaging $19, were extracted from the Grant by the owners of the Canada Hill or Charonnat vein between 1879 and 1887. The vein is narrow and contains very much arsenopyrite, besides pyrite, zincblende, galena, and some coarse free gold.

The Beckman, with which the Mayflower vein found higher up on the hill may be identical, is the most important vein in the complex. It dips very gently south, being at times flat, or even rolling over with a northerly dip. The vein is seldom over 12 inches wide and the walls are very ill defined and irregular, the argillite being bleached and filled with calcite, pyrite, and arsenopyrite next to the vein. The ore consists of the usual massive quartz with an often considerable amount of zincblende, galena, arsenopyrite, and pyrite. The ore is often high grade, and the free gold unusually coarse, being frequently visible in small particles embedded in quartz, galena, or zincblende. The gold is worth $15 per ounce, or 750 fine.

Faults in the Mayflower complex.—The Butterfly, North Star, and Big Blue—that is, the perpendicular east-west veins—distinctly fault the

Floyd and the Mayflower. None of the intersections being visible at the time of my visit, I rely upon the statements of Mr. W. H. Martin, for many years owner and superintendent of the property. The relation of the east-west veins to the Beckman is shown by the diagram, fig. 13, indicating a relative downward movement of perhaps 20 feet of the sheets between the Big Blue and the North Star. A horizontal projection of the Floyd and the two faulting veins shows the relation indicated in fig. 14, the amount of the faults not exceeding 20 feet.

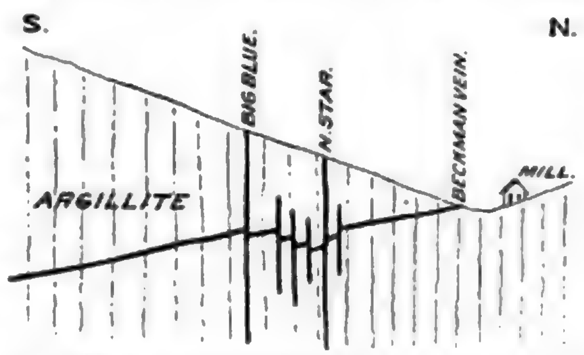


FIG. 13.—Vertical section, showing faults on the Beckman vein, Mayflower mine.

The Canada Hill (*Charonnat*) *vein.*—This vein was worked from 1854 to 1863, but the most extensive work on it was done between 1879 and 1887, in which period the mine produced 19,810 tons of ore, containing about $18 per ton; the exact percentage of sulphurets was 2.8, averaging $90 per ton. The ore yielded $14.80 per ton in amalgamated gold bullion, containing 73 per cent of gold and 27 per cent of silver, and $3.20 per ton in concentrated sulphurets, probably containing much silver. The Canada Hill incline is 1,300 feet deep on the vein and there are over 9,000 feet of drifts; the country rock is a normal granodiorite. The vein strikes north and south, bending to the northwest north of the shaft, and dips 15° to 20° W.; in places it is almost horizontal. It is 15 to 18 inches wide, frequently, however, closing down to a seam. The ore contains, like the Grant, besides free gold, much arsenopyrite, zincblende, galena, and pyrite, and is beautifully ribboned by alternating streaks of sulphurets. Near the cross veins this sulphureted ore is said to change to a more quartzose character, with occasional rich bunches at the intersection. An analysis of the ore showed the presence of tellurium (Mint Report, 1882).

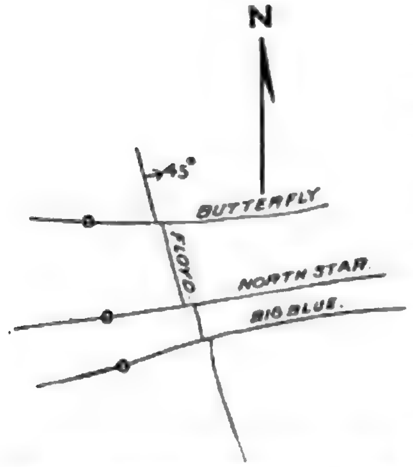


FIG. 14.—Horizontal projection, showing faults on the Floyd vein, Mayflower mine.

Faults on the vein.—Though at present the underground workings are inaccessible, trustworthy information in regard to the well-defined faults on this vein was obtained from Mr. Charonnat, and his information is verified by the underground maps and by inspection of the

cross-seams on the surface. The Canada Hill is crossed by the heavy St. Louis vein, as well as by a great number of other fissures, rarely carrying quartz, striking a little north of east and perpendicular or dipping slightly north. All these throw the Canada Hill vein to the left, going north on the vein. The greatest fault is that produced by the St. Louis, which amounts to 150 feet on the surface and in the drain tunnel, measured in a horizontal direction, which corresponds to a vertical displacement of 45 feet. Between the St. Louis vein and the shaft there are at least two and probably more faults, throwing the Canada Hill an aggregate amount of about 150 feet in horizontal distance; the vein is often cut off as with a knife, as is shown by a portion of the map of the mine given in fig. 16. The rule for finding the faulted vein in the Canada Hill mine is, clearly, to drift in the hanging wall when going north on the vein.

The Grant vein, parallel to the Canada Hill, but dipping east, is apparently not faulted to any notable extent by these cross veins.

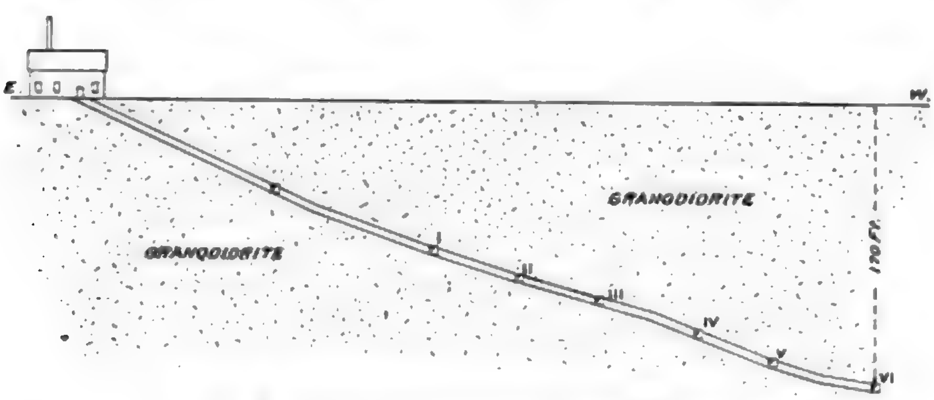


FIG. 15.—Vertical section along shaft, Canada Hill vein.

Comparing the data from the Mayflower and Canada Hill veins, it is clear that the only movement on the faulting veins which can explain these facts is a relative downthrow of the south side, not vertical, however, but inclined toward the east at an angle slightly less than the dip of the Floyd and Grant veins. This explains the large movement on the flat vein dipping west, the slight throw of the Floyd, and the fact that no faults are observed on the Grant vein. The rule for finding the faulted parts of the veins dipping east is thus to drift in the foot when going north on the vein. Many of the faulting fissures are vertical, so that no distinction can be drawn between normal and reversed faults. The St. Louis, however, dips about 85° N., and the fault produced by it is therefore a reversed or overthrust fault.

The Greenman vein, a short distance west of the Canada Hill, dips to the east and, according to Mr. R. Sharpe, intersects the latter without faulting or being faulted. Drusy quartz, galena, pyrite, arsenopyrite, blende, and molybdenite were noted on the dump.

The Wide West is a small vein parallel to the Canada Hill and cropping in Little Deer Creek. It is said to be 1 foot wide and to contain good quartz, but a heavy influx of water in the shaft stopped the developments.

The Union vein.—Located about a mile east of Canada Hill, on the north side of Little Deer Creek, this vein is the most westerly of the

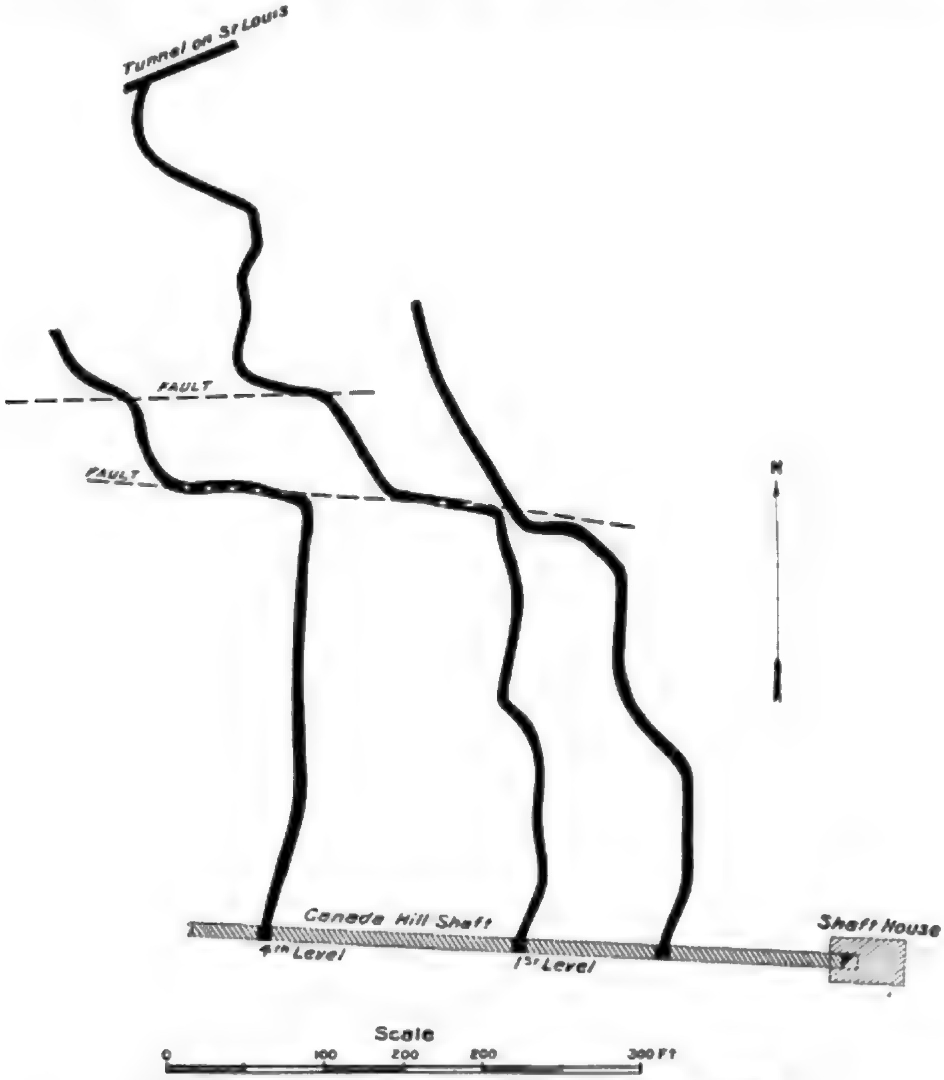


Fig. 16.—Horizontal projection, showing faults on the Canada Hill vein.

Banner Hill complex. It was worked rather extensively from 1863 to 1867, and a little work has again been done on it recently. It is stated to have yielded some rich but mostly low-grade ore, the developments consisting of a 300-foot incline and tunnel from the creek. At a depth of 200 feet on the incline it is stated to cross, without any change in its general character, from diorite into argillite. The dip is 34° E. The width is said to be from 1 to 4 feet.

The Banner vein.—Situated on the western slope of Banner Hill, this vein was located in 1860 and worked most actively during the latter part of the seventh and the beginning of the eighth decade, during which time it produced several hundred thousand dollars. During the year ending June 1, 1871, the mine yielded $135,180. In 1881 the work was resumed farther north on the vein, and the mint report of 1881 stated "the incline (north of the old shaft), now 280 feet deep, will be sunk to a depth of 800 feet before drifting for the old Banner shoot." The work was discontinued two years later, the shoot presumably being found less rich than expected. The old shaft is 670 feet deep on the incline. The vein, striking north-northeast and dipping 45° E., is inclosed in siliceous argillite, similar to that of the Federal Loan, and has a great tendency to split up in stringers, on account of the hard, splintery rock. The vein is said to average 4 feet. The ore contains a large percentage of sulphurets, and great difficulties were experienced in milling it. The tailings from the Banner mine were very rich, and are still being worked by arrastras and other appliances. The pay shoot was, in the upper levels, at least, extremely well defined, 300 to 400 feet wide, and dips N. 45° on the plane of the vein. In 1867 the ore was said to average $20 to $30 per ton, and contained considerable silver.

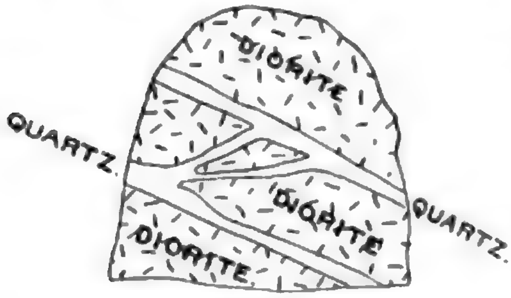


FIG. 17.—Woodville vein, North Banner mine.

The North Banner veins.—The Banner vein can be traced for about 1,500 feet to a point a little south of the diorite contact. North of the creek it is replaced by four veins, which are worked under the name of North Banner, and referred to, going from west toward east, as the Woodville, Dunnington, Tinny, and Reindeer veins. The first is the principal producer, being credited with $175,000 in the mint reports for 1889 to 1892. They are comprised within a distance of 450 feet, and the dip varies from 30° to 45° E. The Woodville is developed by a 1,000-foot-long drain tunnel, at the end of which there is an underground incline 500 feet long, following the ore shoot down. The mine is worked only on a small scale at present. The main Woodville tunnel starts in hard, dark argillite (contact metamorphosed), but strikes the diorite within 100 feet. The veins are entirely in diorite. Strong sheeting, dipping west, is developed at the mouth of the Woodville tunnel, while an equally strong sheeting, dipping east, shows in the vicinity of the Tinny vein. The Woodville vein shows a decided bend to the west in its northern end. The veins are very regular, from 1 to 2 feet wide, and are filled with the usual massive quartz and sulphurets. The country rock is not extensively altered. The veins are comparatively regular, and little of that splintering

noticeable in the argillite veins is to be observed. The sketch (fig. 17) shows the Woodville at a place where it has split into two veins. The ore sometimes contains as high as 5 per cent of sulphurets,[1] consisting of pyrites, galena, molybdenite, and tetrahedite,[1] and is characterized by a remarkably high percentage of silver. The reported product of 1890 was $48,100 in gold and $2,300 in silver, or 2,450 ounces gold and 1,780 ounces silver. The ore yields $10 per ton by amalgamation, and almost an equal amount in sulphurets, the latter containing about $160 per ton, one-half to two-thirds in value being gold, the remainder silver. The pay shoot on the Woodville, though somewhat irregular, has an extent of 500 feet, and dips to the north on the plane of the vein.

There are several claims to the east of the North Banner, located on parallel and similar veins, but very little work has been done on them. Near the top of Banner Hill, in brecciated argillite, are the Tiptop and Peerless veins, striking N. 30° W. and dipping 60° E. The developments consist only of small inclines and tunnels. Some rich specimens were extracted from the decomposed quartz of the Peerless in 1893. In the continuation of these veins southward is the old British America, said to have yielded some low-grade ore. The whole west side of Banner Hill is apparently traversed by a system of parallel fractures dipping east.

The Grand Central vein lies in the continuation of this belt just outside of the limits of the map, 3,300 feet from the southeastern corner, the country rock being black slate. This vein was worked for silver long ago, but without much success, and pyrargyrite, in fact, occurs on it. In the same vicinity are several other quartz veins, from which gold quartz is said to have been extracted to the value of several thousand dollars.[2]

[1] Eighth Rept. State Mineralogist, p. 421.
[2] Bean's Directory.

CHAPTER XV.

DETAILED DESCRIPTIONS—(CONTINUED).

NEVADA CITY DISTRICT.

The productive veins in this district are, on the whole, concentrated in the vicinity of the granodiorite with the metamorphic slate, though only a few of them actually occur on the contact. There are many strong and persistent veins among them, frequently wide and heavily charged with sulphurets. On the whole they contain less silver than the Banner Hill and Willow Valley veins, but more than the Grass Valley veins. The principal veins belong to two systems—(1) the west-northwest to east-southeast veins, with a steep southerly or northerly dip, and (2) the north-to-south veins with a medium easterly dip. The former system is represented by the strong and continuous Orleans mine, and in the northern part of the sheet by the Sargent & Jacobs, on which but little work has been done. The second, to which most of the productive mines belong, consists of a number of strong veins, apparently radiating from a point in the vicinity of Town Talk in directions ranging from north-northwest to north-northeast. The Providence-Champion complex embraces the largest veins in the whole region here discussed, and the considerable faulting which has taken place along it renders it of especial interest. Contrasting with these wide veins and broad faulted zones are the narrow and clear-cut fissures of the Mountaineer and the veins in Nevada City. The intimate connection of the two principal systems referred to above is emphasized by the sudden bend of the Ural vein, changing from a north-northwest to a west-northwest direction, and by the less emphasized bend of the Merrifield vein. North-south veins dipping west are rare and are only represented by the Sneath & Clay and the Mohawk. The extensive seam belt west of the Providence-Champion system forms an especially interesting feature.

A few scattered veins occur in the diorite area about Stocking and Pleasant flats. On one of them, just north of Stocking Flat, a small pay shoot, containing about $1,000, is said to have been found. The veins occur in granodiorite, diorite, sedimentary siliceous slates, porphyrite, and amphibolite, without great differences in the composition of the filling. None have, however, been found in the serpentine. The veins of the Providence-Champion system carry the largest amount of sulphurets, but all of the veins contain in the pay shoots a relatively abundant quantity of free gold.

VIEW OF SUGAR LOAF AND CEMENT HILL FROM NEVADA CITY.

The sheeting of the country rock is not prominent, except in the immediate vicinity of some of the larger veins and along the seam belt. At the latter place it is very well defined, and the joints dip to the west. Outside of the limits of the sheet to the northwest of Coan's mine there is a series of veins, not continuous, however, and not located on any contact. Among these are the Oro Fino, Yellow Diamond, Etna, and others.

The veins of Gold Flat will be described first, then those of Nevada City, lastly the Providence-Champion system and the seam belt.

The Orleans vein.—Forming the continuation of the Glencoe (Gracie) vein in the Banner Hill district, the Orleans can be traced for 1½ miles west of the eastern boundary of the Nevada City sheet. The vein has been a very small producer, no important pay shoots having thus far been found. The developments are also slight. The Orleans tunnel is driven on it a short distance east of where the vein crosses the railroad, and the Orleans shaft, 200 feet deep, is sunk 900 feet east of the lower Grass Valley road. At the upper Grass Valley road the Fortuna mine is located, with a shaft 250 feet deep. The vein shows here several feet of low-grade quartz containing considerable sulphurets. The Live Yankee is a stringer south of the Fortuna, and probably connected with the main vein. No work was done on this property in 1893. Near its western end the vein has been opened by several shafts south of the Crosby shaft on the Providence vein, and a crosscut from the first level of the latter found the Fortuna 500 feet southward. The vein lies nearly the entire distance in siliceous clay-slate, grading over into micaceous schists near the granodiorite contact. The strike is about N. 70° W. and the dip constant 70° to 80° S. Only at the extreme western end does it enter the porphyrite area. It is not, as is frequently asserted, a contact vein. With the present developments the opportunities to study this interesting vein are not good. More extensive prospecting might well develop good ore shoots on it.

The Manhattan is a short vein parallel to the Orleans and near the eastern edge of the area shown on the Nevada City sheet. A statement in Raymond's Report, 1871, page 45, gives the thickness of the vein as 2 feet, and mentions that it showed plentifully in gold and sulphurets. It has not been worked in recent years.

The Morning Star and the Eureka veins.—North of the Orleans vein and just east of the railroad the contact of granodiorite and slate is cut by a number of short veins, striking north and dipping east from 45° to 70°. On the Eureka some work was done many years ago, and a great number of small vertical shafts were sunk to open the vein. The Morning Star was being opened in 1893 on a small scale by an inclined shaft in the slate, and some good ore is said to have been found.

The Sneath & Clay and the Mohawk veins.—These two short veins in granodiorite are characterized by a westerly dip, unusual in this

vicinity. The Sneath & Clay is located a mile south of Nevada City, just east of the first railroad curve. Discovered in 1862 by means of the rich quartz specimen found in the placers just below it, it was worked quite extensively up to 1865, producing about $200,000 and yielding ore from $32 to $180 per ton. From 1865 to 1867 it was also worked, yielding a fair profit, the rock at times containing $40 per ton. Soon afterward it was shut down, and has remained so since then. The vein has a flat westerly dip of 23°, and the incline is run 400 feet down along the ledge. The vein is irregular in size, but averages something over a foot in width. The pay shoots are evidently small,

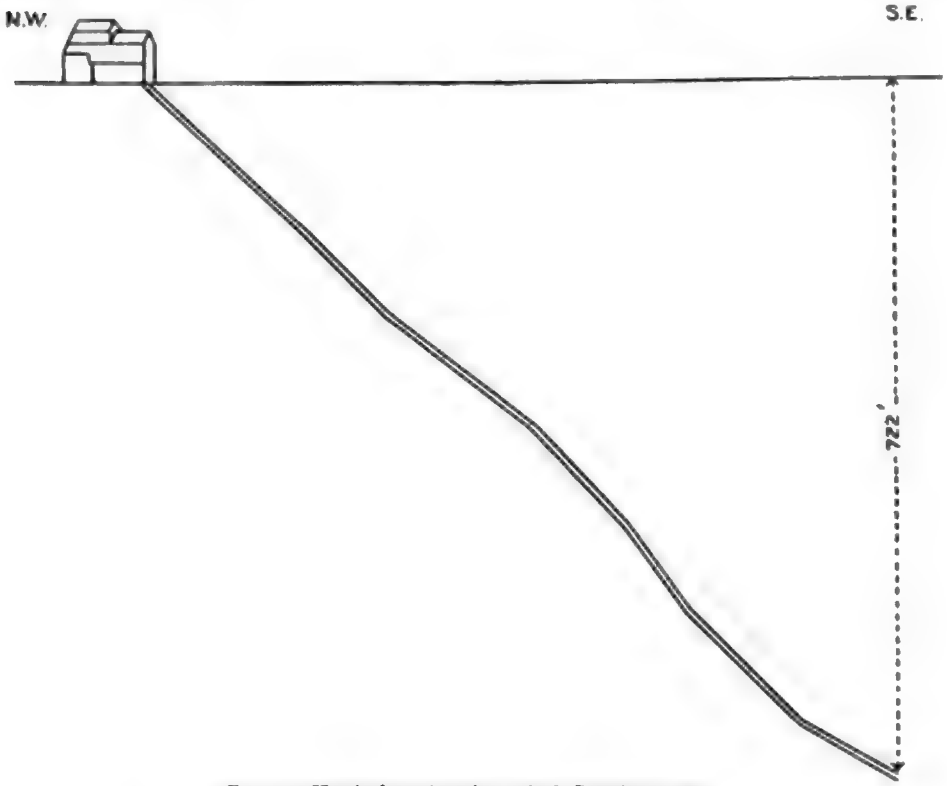


FIG. 18.—Vertical section along shaft, Pittsburg vein.

but rich; the gold, 823 fine. According to T. H. Rolfe, in Bean's Directory (p. 56), the pay shoot in the upper levels is 150 feet in length, contracting below to 100 feet

The Mohawk vein, located half a mile southwest of the Sneath & Clay, was also worked during the sixth decade and opened by a vertical shaft 118 feet deep. At least 500 tons of ore were taken out, averaging $34 per ton. The vein appears to contain rich pockets of free gold, in which many fine specimens have been found. These notes are chiefly from Bean's Directory.

The Pittsburg (Wigham) vein.—This vein was discovered in 1851 and worked at intervals with indifferent success till 1862; in this year it

produced $85,000, with an average of $23 per ton. From 1866 to 1872 the mine produced largely, $102,000 being the yield of 1866,[1] the ore averaging $60, and $150,000 the yield of the year ending June, 1870. In the last twenty years the mine has been worked intermittently; in 1893 exploitation was confined to the fourth and fifth levels south of the shaft. A good report on the property by Mr. J. D. Hague is found in Raymond's fourth annual report. The depth of the main shaft was at that time (1872) 783 feet on the incline.

Present developments consist of an incline shaft with a dip of 43° and a length of 1,000 feet, and an old incline shaft 500 feet long and 400 feet to the south of the main shaft. The drifts of the upper eight levels are extended from 400 to 600 feet north and south of the shaft; from the lowest two levels the drifts have been run for only a short distance. There is a 10-stamp mill on the property.

The country rock is a dark-green, hard diabase, the augite largely converted into hornblende. The croppings of the vein are obscured by the decomposed surface rock; the strike of the vein averages N. 45° E., and the dip 43° SE. with many minor variations (fig. 18). The walls are well defined, the foot wall especially so; the vein is a clean, hard, and compact seam of quartz, averaging in thickness from 12 to 15 inches. Generally the quartz seam fills the entire space between the walls, but in the places where the walls are farther apart the mass between them consists of crushed country rock impregnated with pyrite and calcite, through which two or three veins of massive quartz are distributed. Such an occurrence is shown by fig. 19, drawn by Mr. E. C. Uren, in the now inaccessible ninth level. The pay is in the quartz, the crushed and altered country rock being very poor; "the free gold everywhere present in the quartz is sometimes, though not always, visible. The sulphurets with which much of the gold is associated are generally present, sometimes sparsely distributed in bunches and specks and in other places forming solid seams several inches in thickness" (Hague). Pyrite is plentiful; there is also some galena, but only very little blende and chalcopyrite. Arsenopyrite occurs occasionally. The sulphurets are rich, ranging from $100 to $200, and the ore is in general high-grade, averaging $36, the bullion being 806 fine. The wall rock is remarkably hard and fresh, and frequently lies up close to the vein; the altered country rock, replaced by pyrite, sericite, and carbonate, is confined to the crushed rock between the walls. A remarkable fact is that all quartz in the vein is good ore and goes to the mill. "The pinches or contractions in the vein in the stoped portions are seldom more than a few feet in horizontal measurement, while the expanded portions of the continuous quartz are very much greater, in one case over 200 feet" (Hague). The stopes are very extensive, those on the third level reaching 400 feet north of the shaft and 700 feet southward. While the developments on the lowest levels are small, it

[1] Bean's Directory.

is clear that the pay shoot in this part of the mine has contracted and split in two, one on each side of the shaft. As a whole, the wide shoot may be said to dip to the northeast on the plane of the vein.

The developments to the southwest have generally stopped when a series of fissures faulting the vein was encountered, but, as shown by the work of the last few years on the fifth level, good ore occurs in and beyond the faults. The faulting fissures strike east-west, are nearly

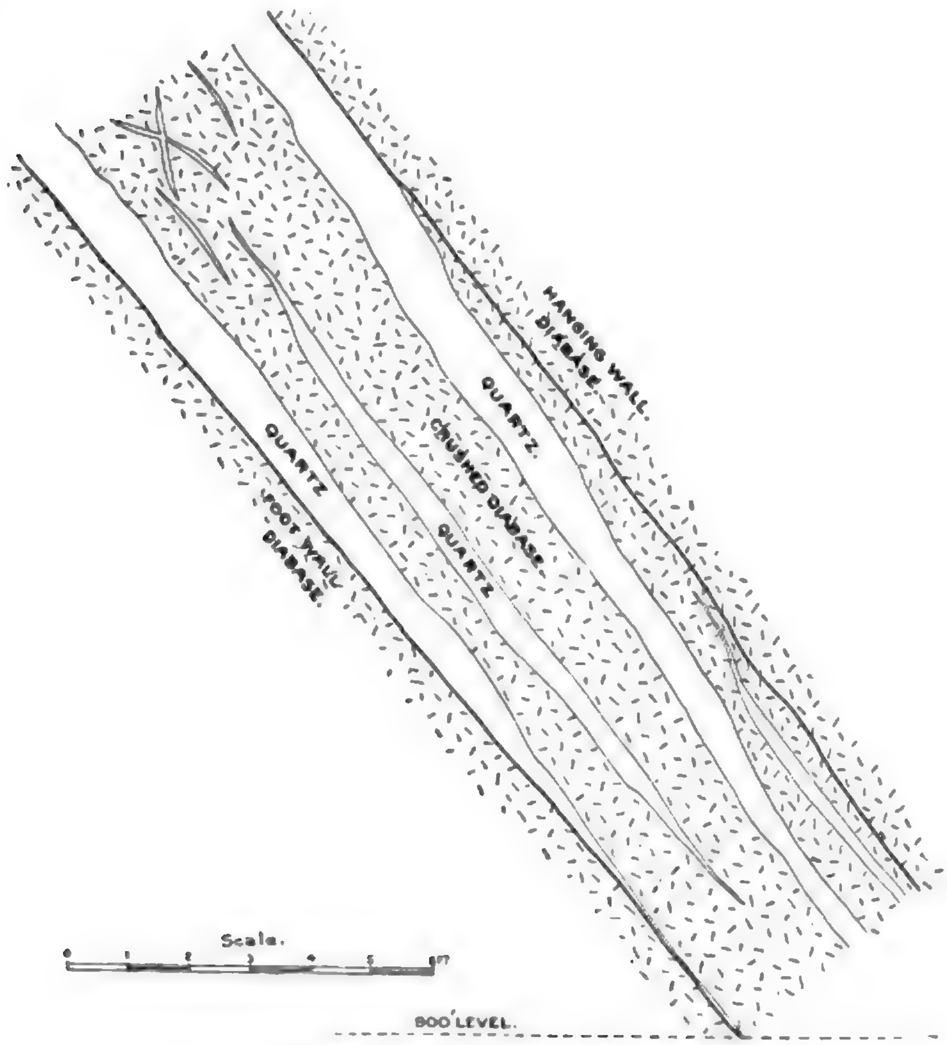


FIG. 19.—Section of Pittsburg vein, ninth level.

perpendicular, and contain no quartz; at least three of them have been recognized, and Hague mentions that the vein south of the old shaft down to the fourth level has been traced through three of these faults and appears to be somewhat enriched by them. Below the fifth level the vein has not yet been followed through the faults. The same fissures are found to fault the adjoining Gold Flat vein. The throw of the faults measured along the drifts does not exceed 40 feet, the north

side generally showing a relative downthrow; that is, the vein will be found by drifting to the left along the fault. The faulting plane is sometimes seen to curve around slightly when the vein is reached, although on the whole following its course without change. In one instance on the third level the vein is bent over, following the fault for a few feet.

The Gold Flat or Potosi vein.—Located 1,000 feet west of the Pittsburg, this vein has been developed at the southern end by the Potosi shaft, 400 feet deep along the incline, sunk about 1865, and 750 feet north of this by the Gold Flat shaft, 300 feet deep, on which work was being prosecuted in 1893 and 1894. There is a 10-stamp mill on the property. The vein is inclosed in hard uralitized diabase or porphyritic diabase, strikes a little east of north, and dips east at an average angle of 38°. It is somewhat irregular in direction and dip, as well as in thickness, the latter ranging from a mere seam up to 18 inches. The sulphurets are not very abundant and consist chiefly of iron pyrites and a little galena; the gold is 816 fine. There are two ore shoots on the vein; one, about 75 feet wide, begins at the Gold Flat shaft and dips south on the plane of the vein, contrary to the general rule, while the other begins at the Potosi shaft, is 425 feet wide, and dips to the north. It is expected that the pay shoots will unite in depth. In 1893 ore was extracted from the shoot in the vicinity of the Potosi shaft, reached by a drift on the 212-foot level of the Gold Flat shaft. At least two barren fissures (crossings) fault the vein, one on each side of the Potosi shaft. They strike east-west, and are perpendicular or incline slightly north or south. In the more southerly of the two faults the vein was seen to be cut off as with a knife by the smooth, glistening seam of the faulting fissure. The throw, measured along the drift, is from 10 to 20 feet, and to straighten the fault it is necessary to drift to the left along the crossing; this corresponds to a downthrow of the northern blocks.

The Mohigan vein.—A few hundred feet northwest of the Gold Flat, and between that mine and the Thomas, is the east-west vein of the above name. It dips 38° S., and would seem to correspond to the flat east-west veins on the Mayflower, Sharpe, and McCormick properties. The Mohigan shows an average width of 1 foot and has been worked for a distance of 800 feet along the cropping, but to no great depth, the shaft being 150 feet deep. The ore is said to have averaged $30 per ton.

The Merrimac vein.—Situated about 2 miles south of Nevada City, on the south slope of the Town Talk Ridge, this short vein shows the somewhat unusual dip of 42° N. It is opened by a shaft 385 feet deep on the incline. The drifts extend chiefly eastward from 100 to 300 feet. The vein lies in the black, tuffaceous Mariposa slates, and cuts their strike and dip. It is said to be from 18 inches to 3 feet wide and to contain a pay shoot 300 feet long. The ore is banded quartz,

containing galena, besides free gold, 817 fine. These notes are from the Eleventh Annual Report of the State Mineralogist, the mine not being worked during 1893 and 1894. The small hydraulic pit near the mine was excavated to wash the decomposed croppings of this vein below the andesite.

The Thomas and Grant veins.—It has already been stated that the principal veins crossing Deer Creek and dipping east converge toward a center in the vicinity of Town Talk. All of them appear, however, to die out before reaching the Fortuna cross vein, and south of that there are only two veins which represent the Deer Creek vein system. On one of them, the Thomas vein, striking north-northeast and dipping 45° E., perpendicular and inclined shafts have been sunk to a depth of 800 feet on the incline. The ore bodies are said to be very irregular, ranging from a few feet to 150 feet in width. The ore is heavily charged with sulphurets and frequently very rich. No work has been done on the property for a long time.

The Grant vein, 1,200 feet north of Town Talk, has been opened by a tunnel. In its southern part, called El Capitan, considerable capital was expended about 1880, without returns. This vein might, from its position, be considered as the southern continuation of the Merrifield.

The Eagle vein.—This is a short vein cropping near the cemetery south of Deer Creek, half a mile east of the bridge. It is opened by a 500-foot-long tunnel from Deer Creek, is said to be 8 inches wide, and contains some high-grade ore. In 1881 the vein was worked to some extent.

Parallel to this are the three larger veins described immediately below. They may be characterized as sharp, clear-cut, single fissures, narrow but frequently rich in free gold, and incased in very hard granodiorite, and may be referred to as the city veins, because outcropping within the limits of the city.

The Nevada County (Italian) vein.—This vein, cropping at several places on Piety Hill, crosses Deer Creek at the suspension bridge and, continuing under the center of the city, splits into two branches. It was discovered in 1866, but has not been worked for many years past. The main shaft near the bridge is 230 feet deep on the incline, but no levels are turned below 200 feet. The first level extends 700 feet north and 50 feet south; the second level, 200 feet north and 500 south. There is a main shoot at the shaft, and two smaller shoots to the north and south of it, all dipping to the north. The dip is 50° E.; the width variable, generally narrow, but occasionally up to 2 feet. The ore runs from $20 to $40. A 3-foot-wide barren and perpendicular cross vein faulted the Nevada County vein about 600 feet north of the shaft, the throw being 6 feet. At this crossing the ore was very rich, reaching $100 per ton.

The Stiles (Midnight) vein.—The southern part of this vein, known as the Half-mile House ledge, has been prospected all along its course and

opened by an incline shaft. North of Deer Creek it has been opened by a tunnel from Deer Creek, and some good ore is said to have been found.

THE GOLD TUNNEL VEIN.

This prominent and rich vein has been worked by the Reward, California, Gold Tunnel, and Pennsylvania mines, along a distance of 7,000 feet.

The Reward mine is located at the southern end of the vein, where it is split up into two branches about 180 feet apart. The Reward shaft, located on the eastern vein, is 200 feet deep on the incline and dips 33° E. A pay shoot on this vein was stoped in 1894. The vein is very regular and of an average thickness of 1 foot of solid quartz. At the depth attained the granodiorite is very soft and decomposed, and most of the sulphurets are oxidized. As a preliminary to sinking, a drain tunnel is being driven from Deer Creek.

The California mine, north of the Reward and on the south side of Deer Creek, was located in 1857 and worked in a desultory manner until 1866, when new machinery was erected; the mine shut down again, however, in 1868. It was exploited again about 1875, for which year it is credited in Raymond's Report with a production of $90,000; for many years past it has been idle. The incline is 540 feet deep along a dip of 37½°, and has three levels turned below the drain, which are from 200 to 500 feet long. The vein is said to vary from 1 inch to 4 feet in width, the average probably being 1 foot; the ore is reported to contain about $19 per ton and 3 per cent sulphurets.

The Gold Tunnel, on the north side of Deer Creek, has the distinction of being the oldest mine in Nevada City, being located in 1850. From 1852 to 1855 it is known to have yielded $300,000, averaging $50 per ton; from 1855 to 1863 it was worked continuously, with unknown output. In 1868 the ore above the tunnel level was not yet exhausted. It was worked more or less continuously until a short time after 1875, since which time it has been idle. The vein is opened by a long drain tunnel from Deer Creek, connecting with the old incline halfway up the hill and with the new shaft on top of the hill. The latter is sunk 360 feet on the incline below the tunnel, two levels being turned, the lowest 250 feet below the drain. There appear to be several pay shoots on the vein. The width of the vein, while variable, is said to average 1 foot 2 inches, and the ore contains 2 per cent sulphurets.

North of the Gold Tunnel lies the *Eddy claim*, reported to have produced some ore, and the *Pennsylvania*. The latter mine, which has not been worked for many years, lies northwest of Nevada City, and its shaft is started in the Neocene gravels covering the vein. According to a report in the possession of the Citizens' Bank, the shaft is 500 feet deep on the incline, with drifts 400 to 500 feet long on each side. The dip is 45°, with good foot wall; the size of the vein, 18 to 24 inches, mostly ribbon rock. About 15,000 tons have been extracted, yielding $20 in free gold and 8 per cent sulphurets, the latter containing $100 per ton.

THE MOUNTAINEER VEIN.

Extending from Deer Creek for at least 5,000 feet northward, this vein is, in the character of its fissure, related to the city veins, though its ore is more like that of the Providence system. It has been worked extensively for the last fifteen years, and is estimated to have produced $1,000,000 in this time. The principal developments are in the southern part of the vein, but it has been traced over the exposed bed rock of the hydraulic diggings, where it shows as a small seam, and bends to the north-northwest, one branch extending north-northeast. Some ore assaying $80 was extracted near the large pond in the diggings, and the same vein is shown 4 to 5 inches thick in the Grover and Knickerbocker tunnels.

The Mountaineer mine is opened by a tunnel from the north side of Deer Creek. One thousand feet from the mouth a shaft is sunk 850 feet deep on the incline. Seven levels are turned, with a maximum extension of 1,100 feet to the north and 650 feet to the south. A 20-stamp mill is erected on the property. The vein is clear-cut and well defined, with a direction of N. 18° E., and dips 37½° E. on the tunnel level. It is inclosed in very hard granodiorite, the fresh rock generally lying close up to the vein. The width averages about 1 foot, but is very variable; when it occasionally swells to 3 or 4 feet the ore usually becomes poor. There is no sheeting of the rock adjoining the vein, but the quartz forming the filling is frequently ribboned by sheeting and crushing; much pyrite, often also gold, is found on the sheeted faces. The sheets of quartz, 1 inch or less thick, often show pronounced striation, which is perpendicular to the strike, or dips slightly northward. The quartz contains, besides free gold, much sulphurets, the average being 3 or 4 per cent, consisting chiefly of pyrite, with much greenish-black blende and some chalcopyrite and galena. The sulphurets are rich, containing from $100 to $200 per ton. No arsenopyrite was observed. The ore is characterized by a considerable percentage of silver, and is said to average $15, the product of the mine being as follows:

Year.	Gold.	Silver.
	Ounces.	*Ounces.*
1890	4,262	2,341
1891	3,507	2,260
1892	3,552	2,000

The principal pay shoot begins at the reservoir on top of the hill and pitches a little north on the plane of the vein. On the fourth level the vein had shut down to a mere seam where the pay shoot should be, but opened up rich again on the next level below. Beyond this shoot the vein forks and has not been explored. The third, fourth, and fifth

levels extend 200 feet south of Deer Creek. In the hanging wall, 170 feet from the main fissure, is found a heavy but mostly barren vein called the Black Prince, connected with the Mountaineer by a cross fissure.

Three cross fissures, striking northeast and dipping 60° N., cut the vein in the vicinity of the shaft on the tunnel level. They do not carry much quartz, and are stated to have faulted the vein 1 or 2 feet in some places. The massive quartz, without sulphurets, between the pay shoots averages $1.50 or $2 per ton.

THE MERRIFIELD VEIN.

The Merrifield vein is probably the longest one in the district, and forms, with the adjoining Ural vein, one of the most important vein systems of the district. The Providence, Merrifield, Spanish, and Mount Auburn mines are located on it, and there can be hardly any doubt that it is the same Merrifield vein which emerges from the volcanic capping on the north side of Cement Hill (northwest corner of map) and continues down to Hoyts Crossing. In such case the total length of the vein would be over 4 miles. The principal developments are on both sides of Deer Creek.

The Providence mine, on the south side of Deer Creek, was located early and worked on a small scale between 1861 and 1867. Considerable difficulty was experienced in treating the highly sulphureted ore, Knox pans being used to extract the gold from the concentrates. The exploitation of this and adjoining veins on a large and profitable scale really dates from the time of the introduction of the chlorination process. Since 1870, however, the mine has been worked almost continuously, with a short interruption about 1888, and with gratifying success. In the last years considerable ore has also been extracted by the Providence mine from the adjoining Ural vein. The mine is equipped with a 40-stamp mill and chlorination works. The total output of the Providence mine, or, indeed, of any of the mines on the Merrifield vein, is not accurately known. The Nevada County Mining Review estimates that the Providence has yielded $5,000,000 since its discovery, which figure, however, seems too large. In the mint reports of 1890 the mine is credited with $59,000, but the average output since then has doubtless been considerably larger.

The present developments consist of a shaft 1,800 feet on the incline and drifts on the vein aggregating several miles. The mine has been opened underground to south of the Crosby shaft, as illustrated on Pl. XXI. This plan is not intended to represent the complete workings, but only so much as may be necessary to an understanding of the important geological features involved.

The Merrifield vein is notable for its great width, and particularly for the great width of crushed material accompanying it. In fact, in this regard the Ural and the Merrifield stand alone in the districts; everything points to most intense dynamic action along these lines.

To the north of the Providence mine the Merrifield vein lies entirely in granodiorite; at that mine it cuts the slate contact obliquely at a slight angle, evidently following the latter on the surface for a few hundred feet, though the exposures are not quite decisive on account of surface decomposition. The relations of the slate and the granodiorite are particularly interesting in the Providence mine. The lower workings are all in granodiorite. In the drain tunnel, however, about 800 feet from the entrance, the vein encounters the contact and follows it as far as the drain is accessible at present. Both the hanging wall and the foot wall are very much crushed and decomposed, but enough is visible to justify the assertion that the vein follows the contact. The workings below the tunnel are not now accessible, but it is well known that the vein for a considerable distance below it followed the contact. A part of the data represented on the map are furnished by Mr. Thomas, for a long time the superintendent of the mine and probably better acquainted with the old works than anybody else. Now, as far as is known, the veins of the district exhibit the most marked indifference as to crossing or following any contacts; it is further known, from examinations covering a large area in the Sierra Nevada, that the contacts of the granitic rock with the slates either run wholly irregularly or—and this very frequently—are approximately vertical. It is very improbable that the contact should have happened to follow a plane which subsequent forces caused to be a fault plane. Taken in connection with the indications of intense crushing along the vein, the only rational explanation is that an overthrust fault has taken place with a relative upward movement along the hanging wall, amounting to about 1,000 feet measured along the dip of the vein. Indeed, if we assume an approximately vertical contact and a line of fissure crossing it at a slight angle, an upward movement of the hanging wall will place a part of the vein on the contact, producing a contact area extremely similar with that shown by the workings of the mine.

The vein strikes about north-south and dips 35° E. on an average, different parts dipping from 29° to 45°. Between the fresh unaltered walls there may sometimes be as much as 20 feet, or even more, of rock more or less crushed and divided by numerous fissures parallel to the vein. As a rule this "formation" is from 6 to 10 feet wide, though sometimes the fresh unaltered rock may be seen close to the vein. The quartz vein proper usually ranges from 6 inches to 4 feet in width, in isolated places reaching 10 feet. This solid, hard, milk-white quartz, not mixed with country rock, constitutes the ore. It contains much sulphurets in ribboned arrangement, partly due to primary deposition, partly to subsequent shearing. Where the width of quartz is extreme the ore is usually poor; for instance, on the 1,250-foot level next to the shaft. It must not be imagined that the ore follows a well-defined plane within the crushed and fissured zone. On the contrary, the quartz vein thins out in one plane only to appear in another, or there may be two or three

VIEW OF CHAMPION AND HOME MINES FROM PROVIDENCE MINE, LOOKING DOWN DEER CREEK.

more or less nearly parallel veins within the zone. The crushed granodiorite is seen in all stages of the process, from a mere softening down to a point where the rock is converted to a grayish-green schist with smooth, curved cleavage faces, and all its constituents flattened and squeezed. The slate, whenever present along the vein, has suffered in a similar manner, and there may sometimes be considerable difficulty in determining whether a given specimen is crushed slate or granodiorite. Analyses of these rocks are given on page 149. The crushed rock next to the vein contains much calcite by replacement and as small seams; considerable pyrite is also usually present. This altered and partly replaced wall rock carries a little gold, sometimes as high as $2 to $3 per ton.

The quartz contains, on an average, 6 or 7 per cent of sulphurets, consisting chiefly of pyrite, chalcopyrite, zincblende, galena, and a very little arsenopyrite. The free gold is very rarely visible. The distribution of the sulphurets is somewhat irregular, and on the whole there is less of them than in the Ural vein. Tellurides, while occurring on the Ural vein, are not definitely known from this vein. Molybdenite occurs rather frequently, and sometimes in large bunches, though usually not closely associated with the other sulphurets.

The concentrated sulphurets are said to assay from $80 to $225 per ton,[1] averaging $130, and contain considerably more silver than gold by weight, the relation being 3.5 ounces of silver to 1 ounce of gold. The gold is rarely visible to the naked eye. In 1890, according to the mint report, the mine produced 2,800 ounces of gold and 2,326 ounces of silver, or approximately equal quantities by weight.

The pay shoots on the Providence-Merrifield vein are rather irregular, size and value of vein often changing, but on the whole it may be said that the most important shoot follows the remarkable split of the vein shown in the plate, and dips to the north about 70°. The width of the fissured zone renders frequent cross cutting necessary.

The Merrifield mine, now owned by the Champion Company, is opened on the northward continuation of the Merrifield vein. According to Bean's Directory, this mine, formerly called the Soggs or Nevada Company, worked nearly continuously from 1857 to 1867, the yield ranging from $40,000 to $70,000 per year. In 1866, 5,000 tons were produced, yielding $42,000 in the mill and $8,000 in sulphurets. The mine was at that time developed by three tunnels, from 2,500 to 1,800 feet long. Between 1880 and 1884 work was resumed, with varying success. A shaft 900 feet deep was sunk opposite the Providence, and the drifts were said to aggregate 8,000 feet. The daily output of ore in 1882 is said to have been 55 tons. Since 1884 but little has been done, and during this examination the old works were not accessible. Recently it has been stated that the intention is to reopen the mine. From information available it is clear that the vein and the filling are entirely

[1] Sixth Ann. Rept. State Mineralogist.

similar to those of the Providence mine. The vein and vein matter are wide, from 3 feet to 16 feet, and average 5 feet. Amount of sulphurets, 6 per cent. From the account it is plain that large ore shoots have been found in the mine, and it would be strange, considering the general character of the vein, if these shoots did not continue in depth. North of the Merrifield mine the vein of the same name is barren for some distance, though easily traceable on the surface.

The Spanish mine is located 1 mile north of Deer Creek. The pay shoot at this place has been worked in a somewhat extensive manner only during the last few years. The property is developed by a shaft, at present 400 feet deep, and the ore is worked in a 10-stamp mill. The Merrifield vein appears here with somewhat changed characteristics. It lies in granodiorite, striking north-northwest and dipping 45° E. The vein is exceedingly variable in thickness, sometimes swelling to 8 or 9 feet of quartz, with some intercalated masses of altered country rock, then again pinching to a mere seam. The granodiorite is crushed near the vein, sometimes schistose, and in some places traversed by seams of black clay parallel to the vein, a product of extreme crushing. The altered granodiorite is filled with pyrite to an unusual degree, but the mass contains very little gold. In extreme form the altered granodiorite is a soft white rock with a greasy feel, consisting of carbonates, residual quartz, pyrite in sharp cubes, and sericite in extremely fine and talc-like scales. Calcite occurs sometimes with quartz as large cleavage pieces. The ore, which is generally low-grade with occasional very rich bunches, consists of solid quartz with a moderate amount of pyrite, galena, and zincblende. Coarse gold rarely occurs and ribbon quartz is not often seen. The pay shoot, said to be 150 feet wide, pitches north on the plane of the vein at a steep angle.

North of the Spanish mine the vein forks and runs blind on the surface for some distance, but there can not be much doubt that the Mount Auburn mine represents its continuation northward.

The Mount Auburn mine.—This mine has not been worked for many years. In the mint reports of 1881 and 1883 it was said to be working, but it must have stopped soon afterward. The shaft is 400 feet deep on the incline, and various levels run northward. The vein is said to be 18 inches thick, and strong in sulphurets, the pay shoots being very irregular. North of Mount Auburn, at Ragon's, the vein splits up into several almost parallel branches. The vein was struck again in the workings of the old Empire gravel mine.

THE URAL AND WYOMING VEINS.

The Ural vein can be traced continuously on the surface from the Providence mine to the Chapman ranch, a distance of 7,000 feet, and probably also continuously from there to the Coan mine at the edge of the tract. For a considerable distance north of Deer Creek the vein follows the contact between granodiorite and slate, and shows

a remarkable tendency to throw out parallel stringers in the latter rock with slightly less dip than the main vein. In the Providence ground the vein has been worked during the last few years by means of crosscuts from the main shaft on the Merrifield vein. North of the creek the Ural vein has been worked for a long time, being known also as the New Years vein. Located in 1851, it was worked for many years without much success. Since 1881 the Champion Company has developed the vein, with excellent results; a 30-stamp mill and chlorination works are built on the property.

In the *Providence mine* the vein has produced a large amount since 1893. In the Champion ground the output has also been large for a number of years, the mint reports crediting that mine with sums ranging from $77,000 to $158,000 in the years 1889 to 1892. The whole production of the Ural vein can not be stated with accuracy, but is probably not less than $2,000,000.

On the surface the vein first appears near the Providence chlorination works, in slate; crossing the creek, it is next seen at and above the Champion Hoist, here on the contact. Making a sharp bend to the west, largely caused by the rapidly rising hill, it continues north, at first not strictly on the contact, for immediately to the east there are a couple of hundred feet of very highly contact-metamorphosed slate mixed with granitic dikes, before the main contact is reached. Soon, however, the often heavy quartz croppings lie distinctly on the contact, and continue so at least up to the Nevada City southern shaft. Though the surface is very much decomposed, the croppings may be traced with considerable accuracy by aid of the frequent cuts and tunnels.

The average dip of the vein is 35° E., and it may be said to vary between 30° and 40°. Near the 600-foot level in the Providence mine it reaches the contact, and follows it strictly between that level and the 1,250-foot level, the lowest at the time of this examination.[1] The rich pay shoot between these levels lies along the upraise not far south of the main Providence shaft. Only on the 600-foot level has the vein been followed to the southward, and the exposures there are of great interest. The crosscut is in hard, massive granodiorite; the vein lies directly on the contact, with strong evidence of movement and crushing of both rocks. Southward, the granite soon leaves the hanging wall and the vein closes down to a persistent and distinct seam. The drift is now in a hard, massive, dark rock, containing occasional small granodiorite dikes; this rock is a considerably decomposed diabase, containing calcite and pyrite, and is evidently a body within the slate, which does not show on the surface. Six hundred feet from the crosscut the seam bends around to the east and becomes very much less distinct at the end of the drift, which is all along in the same diabasic

[1] In 1895, a crosscut, started from the 1,800-foot level on the Merrifield vein, reached the Ural vein in about the same distance as on the 1,250-foot level. The vein is at this depth still on the contact.

decomposed rock. Three hundred and fifty feet from the contact, branch seams start to the east and west; the one to the east has been followed for almost 1,000 feet; it soon bends south again and enters the normal black siliceous slate having a pronounced jointing dipping west; the seam opens to a well-defined vein with as much as 16 inches clean quartz, and dips from 20° to 30° E.; no ore shoots have been found on this vein.

This level has been described in more detail because it is a remarkable instance of the sudden ending of a strong and heavy vein.

The strong pay shoot between the 600-foot and the 1,250-foot levels is about 150 feet wide and dips with the vein. Over this considerable area the vein is from 2½ to 3 feet wide, showing only white quartz mixed with much sulphurets. On both sides of this quartz lie 1 to 4 inches of soft black clay; and in the hanging wall there are usually several feet of greenish-gray, schistose, and crushed granodiorite impregnated with calcite and pyrite. In the foot wall there are also ordinarily from one to several feet of soft, black, crushed, slaty material, derived from the somewhat carbonaceous, contact-metamorphosed schists. The quartz shows no comb structure, but very clearly a ribbon structure, chiefly due to deposition of the sulphurets in large, irregular, roughly parallel masses.

The quartz divides easily in plates from 1 to 2 inches wide, and a close inspection will reveal a slight striation on these sheets, indicating a sheeting of the vein subsequent to its deposition. Small secondary fractures, filled with pyrite, sometimes cross the vein. The vein in this pay shoot is clearly and unquestionably a once open space filled with quartz and sulphurets. Near the 1,250-foot level the vein throws out flatter stringers in the foot wall, with good ore. The "slate vein" found on the 600-foot level is undoubtedly a continuation of one of these stringers. The percentage of sulphurets varies from 5 to 8 per cent; occasionally very heavy masses are found, containing $100 and above per ton. The sulphurets found are pyrite in predominant quantity, galena, zincblende, and chalcopyrite; there is very little arsenopyrite.

A considerable mass of altaite, or telluride of silver and lead, was found in 1894, and was accompanied by free, coarse gold, not otherwise usual in this ore. A little molybdenite also occurs. The concentrated sulphurets contain more silver than gold, the relation being 3.5 ounces of silver to 1 ounce of gold, but in the whole output of the mine the gold predominates by weight as well as by value. The gold obtained by amalgamation is 832 fine. Heavily sulphureted ore was found to contain 5 ounces of gold and 10 ounces of silver.

In the *Champion mine* the character of the ore is very similar to that just described. The sulphurets average 5 per cent and contain from 4 to 7 ounces of gold and 10 to 15 ounces of silver per ton.[1] There are

[1] Eleventh Ann. Rept. State Mineralogist.

several pay shoots of lower grade north of the shaft, and one richer to the south of it; the shoots in general dip north on the vein at steep angles. The grade of the sulphurets and the ore is about similar to that just described. A little molybdenite has been found in the vein here also.

The heaviest body of quartz known in the mine lies in that peculiar sharp bend in the vein to the south of the shaft. In this place were noted 10 feet of massive quartz, with much sulphurets in irregular distribution, not ribboned.

The Champion mine being closed on account of legal injunction during the time of the examination, the opportunities for examination were not so good as might have been desired. Along the shaft and in the several levels in the vicinity of the shaft the Ural vein certainly lies on the contact between slate and granodiorite, and it is stated by all conversant with the character of the vein that the whole deposit, as far as known, lies on this contact. In special cases it may not always be easy to decide, but in general there is no difficulty in distinguishing the crushed slate from the granitic material. On the whole, the vein is very much like the Merrifield and the Ural in Providence ground. There is always a "formation" of crushed, more or less schistose material from 8 to 10 feet thick; the pay—that is, the quartz—may vary from a mere seam up to 10 feet in thickness.

A continued strong tendency to throw out branches in the foot-wall slate is noted in the Ural vein. Immediately north of the creek lies the Wyoming vein, a branch worked many years ago. This vein has a more northwesterly strike than the Ural, dips about 25° E., and distinctly joins the Ural along a line running east-west in horizontal projection. Some distance north another "slate vein," also called the Wyoming, and which may or may not be the same as the one just mentioned, appears, and can be easily traced up to a point at the South Nevada City shaft, where it joins the main Ural vein. On this vein, which dips flatter than the Ural and will eventually join it, a shaft has been sunk to a depth of 900 feet on the incline; the principal work was done between 1880 and 1890. The vein lies entirely in brownish, somewhat flinty, contact-metamorphosed slate, often filled with pyrrhotite. The width is irregular, averaging 2 feet; the sulphurets amount to 2¾ per cent; the pay shoots are very irregular, but a large amount of ground on both sides of the shaft has been stoped.

In the *Nevada City mine* (*Gold Hill Mining Company*) the Ural vein has been extensively worked since 1879, and after a short interval of inactivity work has recently been resumed on it with excellent success. The mine is opened near the southern end of the claim by a shaft 1,000 feet deep on the incline; but no work is being done at that place at present. The new shaft is located 1,100 feet north-northwest of the old one, and is at present 500 feet deep. Pl. XXI shows the extent of the works. The mine is said to have produced $600,000. (Nevada County Mining Review.)

The slate vein and the main Ural vein, uniting at the southern shaft, continue northward, the exposures on the surface at first being unsatisfactory; it is said, however, that the vein followed the contact for some distance.

Seven hundred feet north of the shaft the vein forks. One branch continues northward in the granodiorite and is known as the Muller and Walling; a small incline shaft has been sunk on a branch of this vein a short distance south of the main road. Though the outcrops are unsatisfactory, it is probable that the Muller and Walling makes a bend and continues to connect with the "old mine" indicated on the map, northwest of the Spanish mine.

Another and smaller branch runs out in the granodiorite, makes a bend, and soon returns to the main vein both on the strike and dip. The main branch also leaves the contact and makes a sharp bend to the northwest, soon changing to west-northwest, and continues running a short distance away from the contact and nearly parallel to it. In the old shaft the vein dips 32° E. The workings are not accessible, but it is stated on good authority that the whole vein here lies on the contact. In the new shaft beyond the bend the vein dips 25° E., the upper part of it being still flatter, for the outcrops lie a considerable distance back of the shaft. At the new shaft the vein lies entirely in granodiorite, except at one place in a crosscut a short distance south of the shaft in the third level, where a projecting mass of fresh, hard, quartzose schist reaches the foot wall. A sharply defined dike of granodiorite is contained in this schist. The hanging and foot walls are generally well developed, the space between them, several feet wide, being occupied by a crushed and altered granodiorite. In many parts of the mine there are several parallel seams, accompanied by crushing, back of the front vein. Going south in the drain tunnel, one finds the contact between granodiorite and the schist or slate at the point indicated on the map, at the first shoot of the old workings. The further extension was not accessible at the time of the investigation.

The vein is ordinarily from 1 to 2 feet wide. One body of quartz, with a width of 12 feet, was found on the fifth level, very soon, however, shutting down again. Immediately on the foot wall there usually lies a soft clay 1 or 2 inches thick and made up of finely ground up material. The ore is in general a massive quartz, with sulphurets in entirely irregular distribution. Only rarely is a ribbon structure met with. Small druses and vugs with quartz crystals are common. Coarse gold is seldom seen. The fineness of the gold averages 810. The percentage of sulphurets, varying greatly, may average 2½ per cent. The sulphurets, consisting of prevailing pyrite with chalcopyrite and less galena and blende, are rich, containing an average of 7.5 ounces of gold and 5 ounces of silver. Hessite, or telluride of silver, and molybdenite have also been found.

Nearly all of the quartz in the Nevada City mine is pay ore, ranging

from $10 to $50, so that the stoped areas practically indicate all important quartz bodies on the vein. In the southern part of the mine there are four ore shoots up to 200 feet wide and dipping somewhat to the north on the plane of the vein. In the northern part the principal pay shoot lies to the north of the shaft and, though more irregular, still shows an indication of a northward trend.

Beyond the Nevada City the Ural vein can be followed across the hill to Chapman's ranch, where it is said to have been exposed by a small shaft. It is probably continuous to the Coan mine, where the vein carries considerable chalcopyrite, and has been opened by an inclined prospect shaft. It here enters the aplite area and its outcrops are not satisfactorily exposed.

It is thus certain that a large part of this vein from the Providence to the Nevada City follows the contact, and it is probable, according to the information available, that practically the whole vein between the points indicated follows it. Considering that the whole character of the vein indicates violent disturbance, the only reasonable explanation of this fact is that an overthrust fault has taken place along the vein, resulting in a displacement of at least 1,200 feet, measured along its dip. In other words, the hanging wall has moved up relatively, pushing the granodiorite over the slate and producing a wide zone of crushing and schistosity. This movement has chiefly been confined between the Nevada City mine and the Providence. It appears that near the former mine the movement has been distributed on the branching seams and gradually decreased. A similar distribution of the movement has taken place in the Providence mine, and it is probable that the sharp bend in the granodiorite contact between the Providence and Champion is due to movement on one of the cross seams. It is certainly a remarkable thing to find a large fault ending so suddenly. The rocks in the southern part of the Providence ground bear evidence of having been subjected to a great wrench. If these conclusions are correct, the Ural vein will soon be found to leave the contact and continue in granodiorite, for the fault can hardly have been much over 1,200 feet. This overthrust movement along the Merrifield and the Ural veins has evidently, between the Providence and the Nevada City mine, had the effect of pushing the contact westward a distance of from 800 to 1,000 feet. While it is reasonably certain that an overthrust has occurred on both veins, the evidence in the case of the Merrifield vein is more conclusive than that from the Ural vein.

JOHN BULL, SEVENTY-SIX, AND KIRKHAM VEINS.

The first two of these veins lie to the north of Coan's shaft, crossing Rush Creek. Some good ore is reported from a small pay shoot on the Seventy-six, while much low-grade ore is said to be found on John Bull. A 400-foot tunnel was run on this vein in 1866. The Kirkham has a very unusual northeasterly strike and a northwesterly dip of 60°. A

good pay shoot was discovered on this vein in 1895. The country rock is diorite, containing many little pegmatitic dikes. The mine is located near the line where that rock gradually changes and is more quartzose granodiorite. In the pay shoot, which appears to be about 200 feet long, the vein shows 2 to 3 feet of somewhat decomposed quartz, with perhaps 2 per cent of sulphurets. The quartz contains some chalcedonite. The walls are very distinct; a few inches of clay with polished and striated surface lies next to the vein. On account of deep surface decomposition, the Kirkham can not be traced far southwest, but traces of gold are said to be found all through the red soil on the southwest slope of the hill.

THE SEAM BELT.

From Deer Creek up toward Indian Flat, 700 to 1,500 feet to the west of the Ural vein, extends a belt along which the rock—contact-metamorphosed schist, amphibolite, and diorite—is extensively sheeted by a system of joints generally dipping west at an angle of 20° or less. This jointing may be seen near the slate ledge in the 600-foot level in the Providence, and in the bluff on which the Home shaft is located. At this latter place it is very distinct, especially in the schist on the east side. A dike of diabase appears to have been faulted by these joints, the hanging wall having moved upward relatively. There is also a less well indicated system of fissures dipping east. Again, in the hydraulic pit west of the Nevada City south shaft, the jointing is well shown in the perpendicular wall of softened micaceous schist, and another system of joints is nearly horizontal.

On these seams a little quartz with very large amounts of coarse gold is often found. The hill to the west of the Nevada City mine, called Red Hill, from the deep, red, residual soil covering it, is honeycombed by little shafts and drifts on these little seams. While a dip to the west is most common, yet flat seams or seams dipping east are also met with. On the west side of the hill, near the contact of amphibolite and micaceous schist, the surface decomposition is very intense; it takes a practiced eye to follow the seams, scarcely marked in the soft red mass of decomposed rock, and often containing concretions of limonite. Along many seams gold is found in large pieces and plates; in 1895 two men are said to have panned out $3,000 in ten days from one of these seams. In the above-mentioned hydraulic pit a successful attempt has been made to wash by the hydraulic process the whole decomposed mass. There is an opinion current that these seams will in depth unite to a larger vein, but no good reason can be found to support such a view.

The *Black Ledge* is a hard bench of micaceous schist on the western side of Red Hill, carrying a little pyrite, the decomposed croppings of which are said to contain a little gold, probably, however, derived from narrow seams.

The seams are found again on the hill west of the Wyoming mill, and in the continuation of this belt south of Deer Creek the *Home* and

the *Cadmus* mines are located. In the former several small veins have been found, dipping northwest, southeast, and east at angles of 30° to 40°, and some of them carrying coarse gold. At the Cadmus, the works of which were started in 1895, there are also several veins, one of them up to 1 foot wide and dipping west. Some coarse gold has been found on them.

ORO FINO, YELLOW DIAMOND, AND OTHER CLAIMS.

Though the great Ural vein can not be traced much farther than to the limits of the special sheets, there are to the west-northwest of the Coan shaft several veins, usually dipping east and extending down toward the river. None of them follow the contacts, and, as the sketch, fig. 20, shows, they are inclosed in different kinds of rocks. The Oro

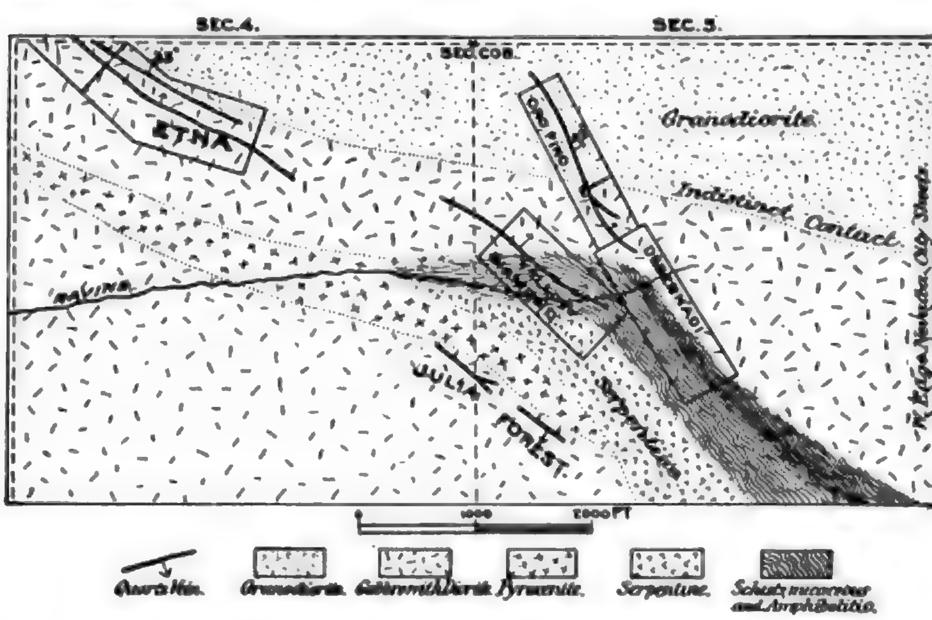


FIG. 20.—Map of Oro Fino and other claims 3 miles west-northwest of Nevada City.

Fino is the most important, and is developed by a shaft 300 feet deep on the incline. The vein dips from 45° to 32°, and strikes north-northwest. The width is said to be about 2½ feet, and there are three pay shoots, one north of the shaft, one at the shaft and 100 feet wide, and finally one narrow but rich shoot south of the shaft. The northern part of the vein lies in granodiorite, while at the shaft it is in a granular rock closely allied to a gabbro. There is a small amount of sulphurets. The Yellow Diamond has a northwest strike and lies chiefly in amphibolitic schists, with serpentine not far away in the foot wall. Several smaller shoots of ore have been found on the Yellow Diamond. In one place the vein is cut and faulted by a steep cross fracture, striking east-northeast. The Julia is a heavy, perpendicular, thus far barren vein; it lies in gabbro and carries some copper pyrite. The Forest

vein dips steeply to the southwest, lies also in gabbro, but near the pyroxenite, and has produced some quite high grade ore containing considerable azurite and malachite. The Dement and Etna are heavy veins, not developed to any extent, and lie in diorite or gabbro near the granodiorite. They also carry chalcopyrite. The Dement can be traced a few hundred feet beyond the limits of the sketch, down on the steep slope toward the Yuba River, but has not been found as far down as the river.

The *Mount George* lies on the headwaters of the main branch of Rush Creek, a short distance north of the main road to Newtown, 3 miles out from Nevada City. It is outside of the special sheets. On the property is a large vein of low-grade ore, striking slightly north of east and dipping about 62° S. North of the vein, two flat seams have been found, containing a ferruginous quartz, dipping in toward the main vein, and some very rich pockets. The two shafts developing the property are less than 100 feet deep.[1] The country rock is gabbro, forming the continuation of the Pleasant Flat diorite area.

[1] Twelfth Ann. Rept. State Mineralogist.

CHAPTER XVI.

DETAILED DESCRIPTIONS—(CONTINUED).

GRASS VALLEY DISTRICT.

The veins of the Grass Valley district, though of great variety in dip and strike, show in their ores and structure a general similarity. The veins are, as a rule, not wide, but the shoots carry high-grade ore. There is very little silver, the Omaha system alone carrying a notable quantity of that metal. Except in that same system, the amount of sulphurets is also below 3 per cent. Pyrite with a little galena, chalcopyrite, and zincblende form the sulphurets. Only in the Osborne Hill system and in the Forest Spring veins is there any considerable quantity of arsenopyrite present. Coarse gold is very frequently met with in the veins.

The Grass Valley veins may be classed in several groups or systems.

THE IDAHO SYSTEM.

The veins in this system, parallel to the great Orleans vein of Nevada City, have a strike ranging from east and west to west-northwest and east-northeast. The dip is usually steep, and may be either northerly or southerly; in certain of the veins, however, flatter dips are observed. The veins are often of greater width than those to the south of Grass Valley, and carry but a small percentage of sulphurets.

THE ALPHA, KENTUCKY, AND SPRING HILL VEINS.

The Alpha and Kentucky are two parallel veins one-fourth of a mile northeast of the Maryland. The developments are slight, consisting of an incline shaft 300 feet deep; the shaft on the Alpha, which is higher up the hill to the west, is 200 feet deep on the incline. The dip is 30° to 50° to the north, and the vein strikes west-northwest. The veins are in serpentine, but a dike of diabase appears near Wolf Creek in the hanging wall of the Kentucky. In Raymond's Report for 1873 the Kentucky is credited with a production of $5,000, the ore averaging $17 per ton.

The Spring Hill vein, about 1,500 feet north of the Maryland shaft, has been developed to only a slight extent by two inclines 200 and 300 feet deep. It is a strong, continuous vein, striking east-west, or in the western end west-southwest, so that if extended it would intersect the Eureka. The dip is 60° N. at its eastern end, changing to 30° on the summit of the hill. The vein lies chiefly in serpentine, but in its

western part there is in the foot wall a rather heavy dike-like mass of an extremely chloritic and altered diabase. The Spring Hill is from 2 to 5 feet wide and contains a small amount of sulphurets in fine distribution. The ore is generally low-grade; though several smaller lots of high-grade ore were milled in 1870.[1] Some work was done on it in 1892 with encouraging results.

THE COE VEIN.

This deposit is on the west side of the road from Grass Valley to Nevada City, about one-half mile from the former. It has been idle for many years past, but was extensively worked twenty years ago. It is said[2] to have yielded $500,000. It is developed by a shaft 554 feet deep on the incline, and three levels run from the same. The vein,

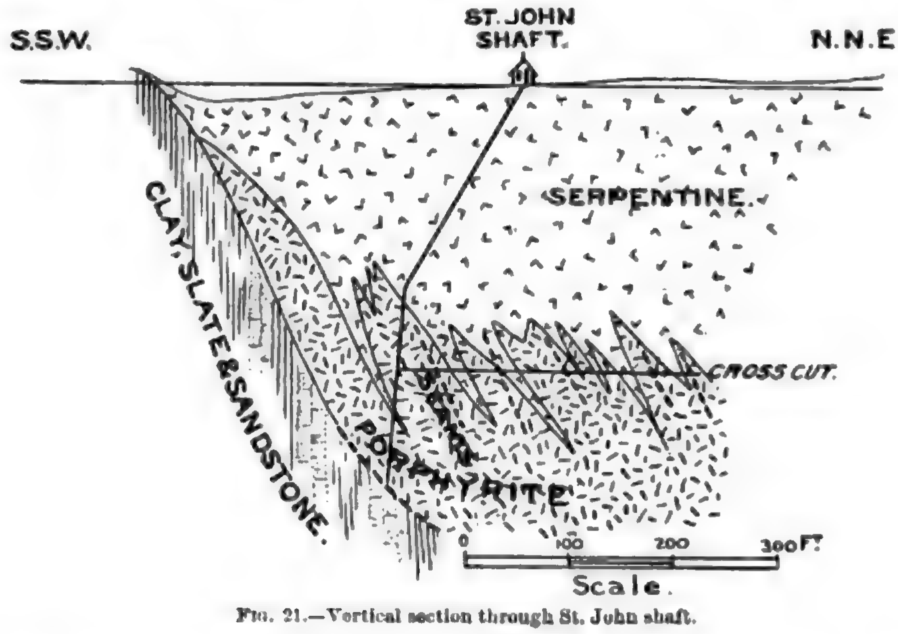


FIG. 21.—Vertical section through St. John shaft.

which lies in serpentine, can be traced for only 1,000 feet west of the road. The strike is parallel to that of the Idaho-Maryland, but the dip is 60° N. It is not, as often asserted, an extension of the vein just mentioned. The outcrops are remarkably strong, showing 3 feet or more of solid quartz. On the west it is said to continue up to the St. John, but there is not sufficient evidence to support this view. Some croppings show at the head of the gulch in which the Coe is located, but it is not beyond doubt the same vein. The ore is said to contain only 1 per cent of pyrite and galena. The extent of the pay shoot is not known; it is reported to pitch to the west.[3]

[1] Eighth Ann. Rept. State Mineralogist.
[2] Nevada County Mining Review.
[3] Tenth Ann. Rept. State Mineralogist.

THE ST. JOHN MINE.

This property, which lies three-fourths of a mile north of Grass Valley, was actively prospected in 1893 and 1894, but is at present closed down. The geological features shown in the workings are of great interest. At the point where the shaft is sunk some quartz appeared on the surface, but no continuous vein could be traced. The shaft goes down to a depth of 220 feet, dipping south at 70°, and from there on to the bottom at a depth of 500 feet it is nearly perpendicular. The serpentine of the surface is found to be replaced by porphyrite, traversed by seams of serpentine (fig. 21). In the bottom of the shaft the contact with the black clay-slate was unexpectedly struck, and on this contact a quartz vein, in one place nearly 10 feet thick. Drifting east the heavy body of quartz soon contracted, and the relations at the face of the drift are illustrated by fig. 22. Between the slate in the foot wall and the serpentine in the hanging wall lie a few feet of slaty serpentine with stringers of quartz, the latter containing some galena and free gold. West of the shaft the vein, or at least a branch of it, goes in the clay-slate, but in a little crosscut in the foot wall it shows again the relations illustrated in fig. 23, the serpentine resting on the clay-slate and separated from it by a polished seam and a small quartz vein. All these facts point strongly to the existence of an overthrust fault along the contact of slate and serpentine. In a long crosscut, shown in fig. 21, a number of seams were met with, almost forming a sheeting of the porphyrite, and most of these carry a little free gold, as shown by prospecting the crushed matter in the pan.

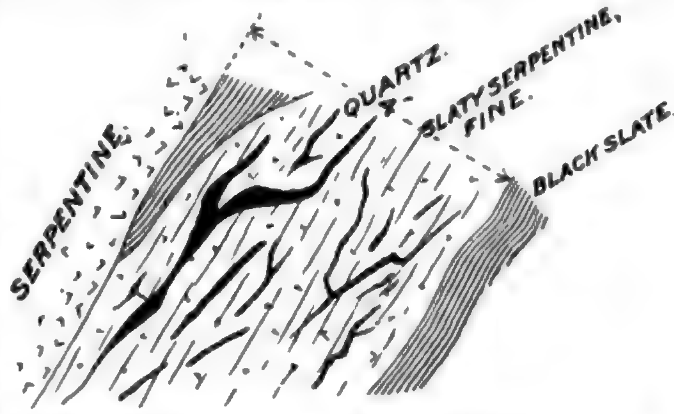


FIG. 22.—Vein in St. John mine, fifth level, 150 feet east of shaft.

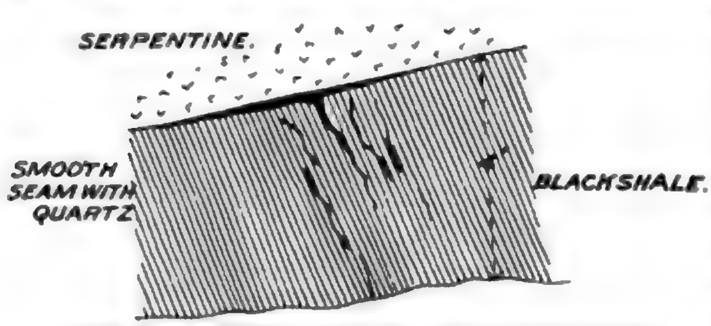


FIG. 23.—Vein in St. John mine, fifth level. 100 feet west of shaft.

THE EUREKA-IDAHO-MARYLAND VEIN.

The ore shoot of this interesting vein has been worked in the Eureka and the Idaho, and is at present exploited in the Maryland. The Eureka, on the western end of the vein, was located in 1851. The vein is indeed here conspicuous by heavy outcrops on the surface; these outcrops were, however, very poor, and from 1857 to 1863 the ledge was worked only to a depth of 48 feet, much quartz, of low grade, being taken out. Finally, in 1864, the vertical shaft was sunk to 100 feet and the main ore shoot encountered. On the Eureka ground the ore shoot was then successfully worked until 1873, when the yield began to decrease, and in 1877 the mine shut down after vain efforts to find the continuation of the shoot to the west. The adjoining veins of Mobile and Roannaise were also prospected toward the end, without success. The Eureka mine produced a total of $5,700,000. Several years the mine produced from 10,000 to 12,000 tons of ore per month, running from $23 to $60 per ton, and averaging $28, at a cost of mining and milling of $10 to $15 per ton.

The Idaho mine, located in 1863, adjoining the Eureka on the east, was worked but little until 1865. At that time a perpendicular shaft was started, striking the vein at a depth of 120 feet, but finding no good ore. In 1867 the shaft was sunk to 300 feet, at which depth the great pay shoot was found. From 1867 the same pay shoot was worked continuously until 1894, when the eastern limit of the Idaho ground was reached. The total output was $11,638,000, the tenor of the ore ranging from $12.76 to $35 per ton, probably averaging $20. The cost of extraction and treatment was from $8 to $10. The output in successive years ranged from a minimum of $183,450 in 1871 to $1,010,600 in 1873. From 1889 to 1892 it ranged from $480,000 down to $226,000. The combined production of the Eureka and Idaho is $17,338,000 in twenty-eight years.

Developments.—The Eureka was developed by a shaft which in 1871 had attained a depth of 725 feet on the incline, and which in the last years of operation was sunk to a depth of 1,200 feet. Below 600 feet, however, no good ore was found. The shaft was perpendicular to a depth of 317 feet, and then followed the pitch of the vein. The drifts extended across the width of the claim, a distance of 1,550 feet. The Idaho is developed by a shaft inclined about 70° from the horizontal, and which attains a perpendicular depth of 976 feet. A short drift extends to the east on that level to the collar of an underground incline, running obliquely on the plane of the vein at an angle of about 40° from the horizontal and attaining a total vertical depth of 2,180 feet, or an elevation of 360 feet above the sea level. From this incline shaft the levels extend eastward to the end of the claim. The Maryland mine is working at present on the same pay shoot continuing eastward, using the old Idaho shaft for the exploitation.

Outcrops and country rock.—The vein first appears in serpentine on

the Eureka ground as very strong croppings of white, massive quartz. Toward the east, in the vicinity of the old Eureka shaft, indications of a chloritic and decomposed diabase appear in the hanging wall; the outcrops are very much less prominent, and are not seen at all east of the Idaho-Maryland shaft. A diabase dike outcrops in Wolf Creek, in serpentine, about where the vein would be expected. At the Idaho shaft a coarse-grained uralite-gabbro appears in the hanging wall, but a short distance east of the shaft the vein must outcrop in serpentine. It probably continues in serpentine all the way up to beyond the Maslin shaft, but until near that point no outcrops are visible; nothing definite can be seen on the hillside, which is covered by deep, red soil; it is possible that a diabase dike follows the vein here, too. At the Maslin shaft, however, the croppings of white quartz in serpentine are distinct, and there can be little doubt that these represent the vein in question. A short distance beyond the Maslin shaft the line of the vein, if continuing straight, would enter coarse, white gabbro, or it may bend a little southward and follow the line between serpentine and gabbro. The old Maryland shaft, 300 feet deep, was sunk southwest of the Maslin shaft to intercept the vein, but encountered nothing but serpentine. Three thousand feet southeast of the Maslin shaft the Chevanne shaft is now being sunk in the serpentine to find the continuation of the vein; nothing but serpentine has thus far been met with, at a depth of a few hundred feet. A quarter of a mile farther southeast, near the Brunswick mill, the Chevanne tunnel, 1,200 feet long, was driven in a northeasterly direction, but without result; the tunnel is in gabbro and serpentine. Small croppings, which may possibly represent the croppings of the Idaho-Maryland vein, have been found 650 feet north-northwest of the Chevanne shaft, near the contact of serpentine and gabbro. Under ground, the vein lies, in many places at least, on the contact of diabase and serpentine, but sometimes the determination of formations is not easy without crosscutting in hanging and foot walls. The average strike is N. 77° W., and the dip is about 70° S., occasionally, however, flattening out to 50°.

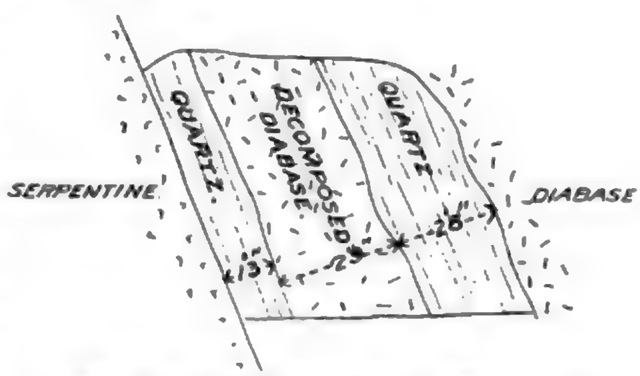


FIG. 24.—Cross section of Eureka vein, on 300-foot level.

In the Eureka ground there are, according to Professor Silliman, two veins, separated by a mass or dike of greenstone 30 feet thick. The smaller of these veins, on the south, has never been worked. The main vein lies, as indicated by fig. 27,[1] between a serpentine foot wall and

[1] Copied from Mellville Attwood in Phillips's Mining and Metallurgy of Gold and Silver, London, 1868.

a dike-like mass of diabase in the hanging wall. The vein is heavy, varying from a few inches to 6 feet, and averaging 3 or 4 feet of solid quartz. On the 300-foot and 400-foot levels in the Eureka a horse of decomposed diabase was met with, dividing the vein in two, as illus-

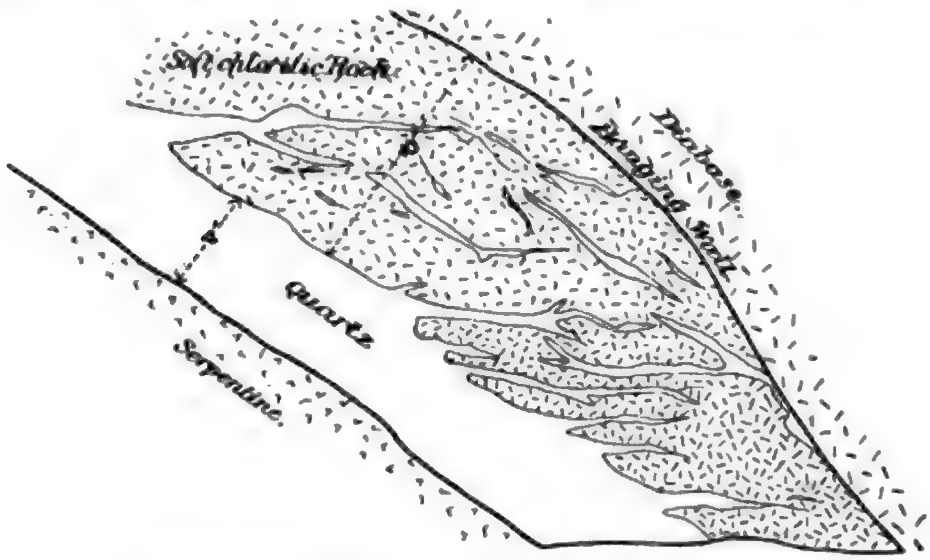


FIG. 25.—Cross section of Maryland vein in stopes above the 1,500-foot level.

trated in fig. 24.[1] The dip for the first 300 feet is 78°, which below decreases to 65° to 70°. This horse varies in thickness from a few inches to 6 feet, and is often filled with quartz stringers, so that the whole mass may be mined. In a few localities both layers of quartz

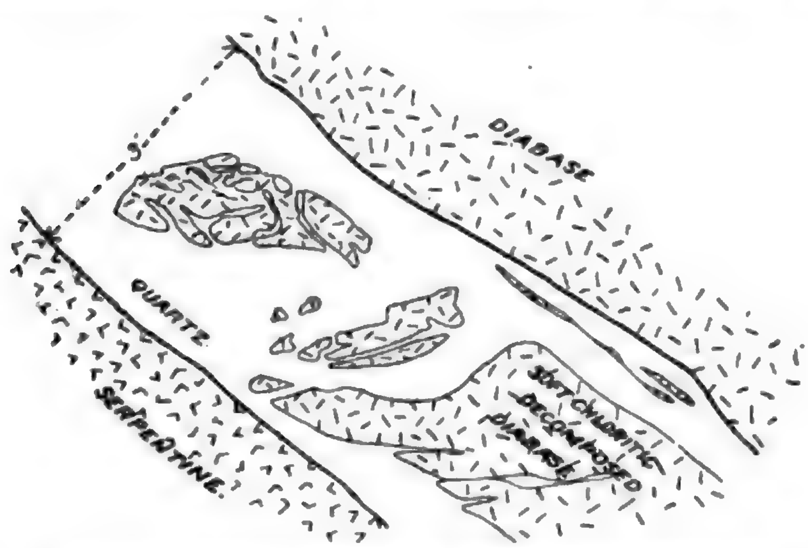


FIG. 26.—Cross section of Maryland vein in stopes above the 1,600-foot level.

come together in the width of the vein, without having the horse between. In these cases there is a line of quartz crystals visible which fill the narrow cavity sometimes left.[2] On the hanging wall there is a

[1] Copied from Melville Attwood in the Eighth Ann. Rept. State Mineralogist.
[2] Raymond's Report, 1872, p. 41.

distinct clay selvage. Concerning the western extension, Professor Silliman makes the following statement (Bean's Directory, p. 233): "The Eureka vein, going west, faults in the Whiting ground, and, having previously become almost vertical, has to the west of the fault a northerly steep dip."

In the Idaho and Maryland mines the vein is equally well defined; the dip is from 73° to 55° S., and the strike very regular; the width of the ore—that is, of the quartz—probably averages 2½ feet. The serpentine is often well exposed in the foot wall, but the diabase is not always distinct. Flaky, chloritic, or serpentinoid soft rock, filled with calcite and cubes of pyrite, often forms the hanging wall; comparatively fresh diabase was noted at the shaft in the seventh and fifteenth levels and at a few other places. A long crosscut, starting from the seventh level and extending 800 feet in the hanging wall, begins in diabase; 25 feet from the vein coarse gabbro begins to appear and continues for 200 feet, mixed with what are probably dikes of diabase; then southward to the face the crosscut is diabase, cut by seams in many directions, but not showing any distinct veins or mineralization. On the whole, the vein was very regular in width and character; in a few places it showed signs of splitting up, but soon increased in strength again. Such places were found in 1875 below the 800-foot level, when the hanging wall went down flat and the ledge broke up in stringers; again in 1882 and 1883 the ore became poor on the 1,100-foot level and the vein irregular; some distance east of the Maryland line, on the 1,500-foot level, the vein splits in two parts, but it has in every case been found beyond strong and reunited. The vein is frequently accompanied in the foot wall by a characteristic gangue of dolomitic rock, sometimes colored green by mariposite, which is to be regarded as a completely altered serpentine. These and other rocks from the Idaho-Maryland are described in detail in Chapter XI. Mr. Attwood states that this dolomite carries a little gold.

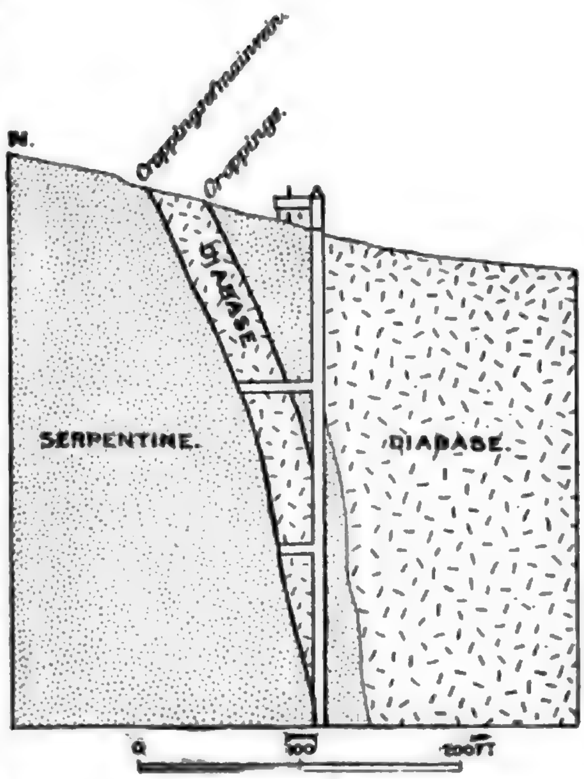


Fig. 27.—Vertical section through Eureka shaft, showing veins.

The ore.—The ore consists exclusively of the solid quartz in the pay shoot, except when the adjoining country rock is impregnated with quartz stringers, as sometimes happens. The chief value in the ore is in the free gold, which as a rule is in fine distribution. Sometimes, however, rich "specimen rock" is met with showing abundant coarse gold. The ore has varied, as stated, from $60 down to $10 and $13 per ton, but an average would probably be about $20. It would appear as if the western part of the pay shoot were somewhat richer than the extension toward the east. The gold is 848 fine; the amount of sulphurets is small, having varied from 1¼ per cent in the Eureka to three-fourths of 1 per cent and 2 per cent in the Idaho and Maryland. The value of the concentrated sulphurets is about $100, sometimes reaching $400. The amount of silver in the sulphurets is small, being stated to be 1.5

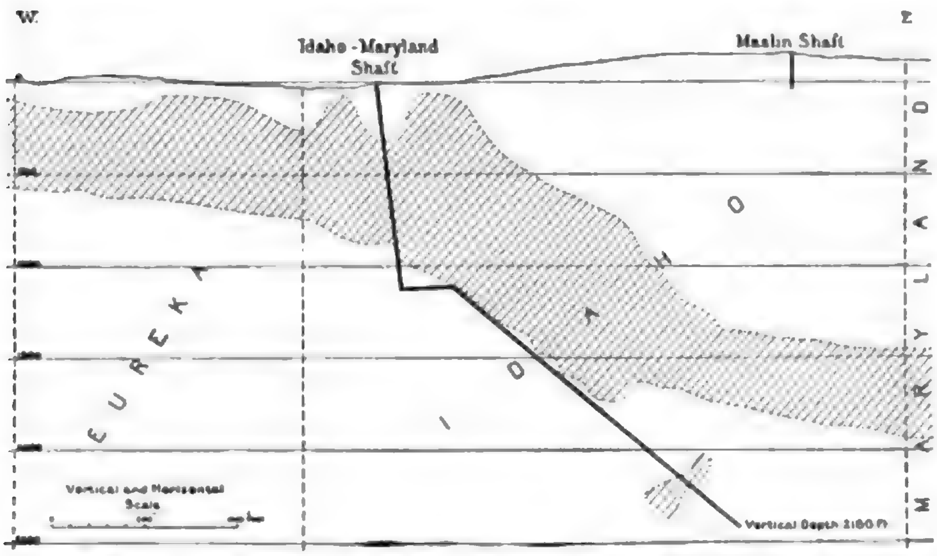


FIG. 28.—Approximate outline of the Eureka-Idaho pay shoot. In projection on the plane of the vein. Dip of vein toward the observer.

cents silver to $1 gold. The sulphurets consist of pyrite, chalcopyrite, and galena, with very little arsenopyrite and hardly any blende. They contain a strong admixture of tellurides, not observed, however, as separate minerals. The sulphurets are difficult to concentrate and to work.

Structure of ore.—The ore is very frequently banded or ribboned. Silliman remarks on this banded structure in the Eureka and says that the joint surfaces are often coated with gold. A banded structure by arrangement of the pyrite in parallel streaks is also noted. Pls. XI and XII[1] show the structure of the Maryland vein. In Pl. XI the ribbon structure is illustrated, due without much doubt to the sheeting of the vein subsequent to its formation. In Pl. XII the vein consists of

[1] From photographs by Victor Dorsey, the superintendent of the Maryland, whose untimely death in 1895 was due to a falling slab of the treacherous hanging wall in his mine.

solid white quartz with no indication of ribboning by sheeting or deposition. Fig. 25 shows on smaller scale the locality of which Pl. XII is a part. Fig. 26 shows the structure of the vein at a place in the stope not far distant from the fifteenth level.

Pay shoot.—The pay shoot of the Eureka-Idaho vein is one of the most remarkable known in vein geology. Its extent and character are shown in fig. 28. Over the whole shaded area it is safe to say that the vein averaged 2½ feet of solid quartz. Outside of these limits the vein grew poor rapidly, and frequently closed down to a mere seam. A vein 2 and 3 feet thick is, however, found in many places outside of the pay shoot, and the physical characteristics of the vein remain the same. Of the eighth level in the Eureka the superintendent stated that the walls were good and regular and 4 feet apart, but the vein was small and very poor. A small pay shoot was found in the deepest part of the Idaho shaft; it was followed for some distance, but eventually proved too small for successful exploitation.

The principal pay shoot has thus been followed for almost a mile with an average dip of 15° E. on the vein and an average width of 600 feet. There is no reason why it should not continue for a long distance eastward, provided the vein does not enter the serpentine; if it does that the probability is that the vein will be found to split up in stringers. The fact that over a large area the vein lies in the serpentine in the foot wall and in diabase in the hanging wall would lend some strength to the view that a considerable overthrust had taken place along it, for the contacts between different rocks are as a rule far from regular. While this is likely, it can not be said to be proved.

THE SOUTH IDAHO VEIN.

Located 2,000 feet south of the Idaho and parallel with it in strike and dip, this vein is developed by a tunnel on the east end and a shaft 100 feet deep on the west. The vein lies in a peculiar mixture of dark-green diabase with coarse uralite-gabbro, in places sheared and serpentinized, the former probably forming a network of dikes in the latter. The zone of thermal alteration is wide, as evidenced by the bleached country rock greatly impregnated with calcite and pyrite, and sometimes colored green by mariposite; seams with large cleavage pieces of reddish calcite also occur. In one case gold has been noted inclosed in calcite. On the foot wall was a distinct and rich stringer of quartz with coarse gold, galena, blende, and pyrites. At a depth of 60 feet this stringer extended out in the hanging wall and splintered up, the veinlets being rich in coarse gold, while the foot wall continued down.

THE BRUNSWICK GROUP OF VEINS.

To the southeast of the Idaho-Maryland is a group of parallel veins which evidently belong to the Idaho system, though the strike has turned more northwesterly. The Brunswick (also known as the English, or O'Connor), with a strike of N. 50° W. and a southwesterly dip

which down to 400 feet is 45°, then becoming 60°, and finally at 600 feet 70°, was located early and has been worked with varying success for a long time, the upper levels containing some good ore shoots. For the last seven years the mine has been extensively prospected, and some good bunches of ore have recently been found in the lowest level. The mine is developed by a shaft 700 feet deep on the incline, and drifts extending 300 feet toward the west. The vein is contained in a chloritic schist derived by dynamo-metamorphic processes from a porphyrite-breccia, and intersects the strike of the schist at an acute angle. There are usually two well-defined walls, 2 to 4 feet apart. The space between the walls is only locally wholly filled with massive quartz, being generally occupied by soft chloritic schists, extensively altered by hydrothermal processes; the schists are either parallel to the walls or, as is frequently the case, broken and irregular; they contain streaks and ramified veins of massive quartz (fig. 29), which sometimes increase in thickness and occupy the whole space between the walls. East of the shaft the vein closes down to a mere seam. Free gold is rarely visible in the quartz, and the sulphurets, which generally are rich, consist of pyrite, chalcopyrite, and galena.

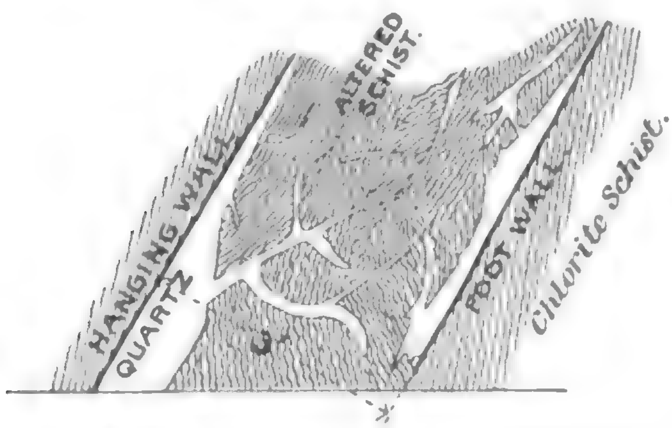


FIG. 29.—Cross section of the Brunswick vein, on 700-foot level.

The Gold Point is a vein parallel with and south of the Brunswick. The heavy croppings, dipping 70° S., can be traced for over 2,000 feet. It is opened by a tunnel from Wolf Creek connecting with inclines from above. To the west of the tunnel the vein is very heavy and contains large masses of low-grade ore. The country rock is a schistose porphyritic breccia, less chloritic than that of the Brunswick.

The Union vein, the croppings of which are visible in places on the north bank of Wolf Creek, is one of the earliest-located veins in Grass Valley. The ore was worked with an arrastra up to 1854. In 1865 mill and hoisting works were erected, and the mine was worked with profit until 1870. The total product is given as $250,000. From January 1 to August 1, 1869, the mine produced 7,200 tons, yielding $75,569, or about $10 per ton. The vein, which is continued in schistose porphyritic breccia, dips 50° S. and has been developed by a shaft 268 feet deep on the incline. The width is said to be considerable, averaging 3½ feet. The extent of the stopes is shown on fig. 30, taken from

Raymond's Report for 1869-70. The gold is 822 fine. Galena is said to predominate in the sulphurets.

The Cambridge vein is located on the south side of Wolf Creek. The Lucky and the Cambridge mines were located on this vein and worked extensively about 1865 to 1868. The Lucky mine, on the west, had a 15-stamp mill and was exploited by a shaft 400 feet deep on the incline, 10,000 tons of ore being extracted from 1865 to 1867. The Cambridge, adjoining on the east, was opened by a shaft 200 feet deep, and a 10-stamp mill was erected on the property; 75 tons of ore per week were crushed for a long time, averaging $20 per ton (Bean's Directory). The vein lies in chloritic schist, dips 50° SW., and is generally wide, averaging 2 to 3 feet. According to Professor Silliman, free gold is rarely visible in the ore. If these reports are correct, this vein, as well as the Union, may be rendered productive again. The gold is from 817 to 820 fine.

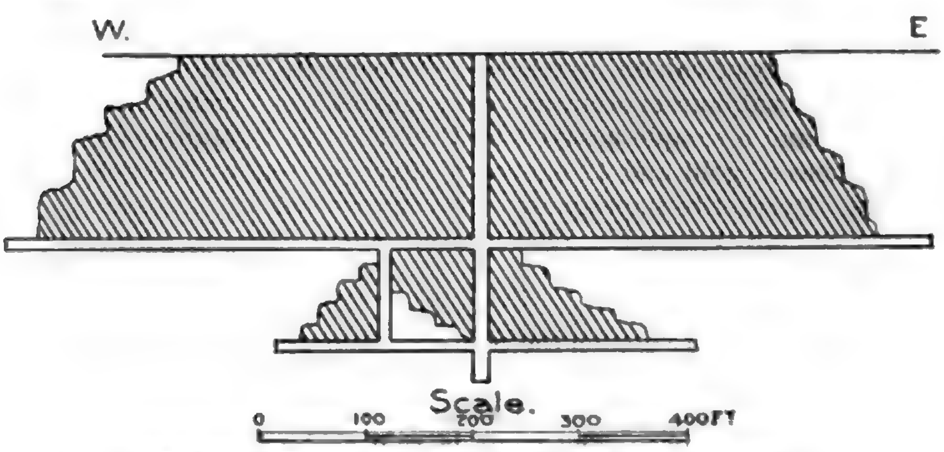


FIG. 30.—Longitudinal section, Union Hill mine, showing areas stoped.

The Francfort vein, about 800 feet south of the Cambridge, is said to have produced some good ore from the croppings.

THE CROWN POINT VEIN.

This deposit, located on the south side of Wolf Creek, half a mile east of the center of the city, has been worked at intervals since 1886. The production is stated to have been $130,000, of which $80,000 was found in one bunch of ore with much coarse gold. The shaft is 400 feet deep on the incline, with levels extending east and west, only the upper two levels being accessible in 1894. The vein, which strikes northwest and dips 70° to 80° N., lies in serpentine or serpentinized porphyrites, the width of quartz and vein matter varying from a few inches to 4 feet. There are considerable amounts of magnesic and calcic carbonates produced from the serpentine by thermal alteration. A thin sheet of quartz, still adhering to the foot wall near the shaft in the drift, shows beautiful polish, with nearly horizontal striation; in

other places the striation in the foot wall is parallel with the dip. The serpentine of the hanging wall is filled with carbonates and pyrite; the ore carries coarse gold and 3 per cent of sulphurets.

The New Eureka shaft, 500 feet deep, was sunk about 1888, 900 feet northwest of the Crown Point shaft, to find the extension of the Crown Point vein. The shaft is inclined 80° N. down to 121 feet, and from that depth is vertical. The upper part of the shaft was in black slate and sandstone, changing at a depth of 150 feet to chloritic and serpentinoid rocks derived from porphyrite and diabase. Highly mineralized zones, rich in pyrite, and with some quartz, were met with at a depth of about 200 feet, but no well-defined vein.

A 20-foot crosscut to the north from the 200-foot level on the Crown Point has intersected a mineralized zone along a fissure dipping in part north, in part south, at steep angles. Along this fissure the country rock is chiefly serpentine, but black siliceous slates are also met with, usually highly impregnated with pyrrhotite. The ore is most unusual in character, differing greatly from the ordinary quartz veins, and consisting chiefly of calcite, pyrrhotite, chalcopyrite, with some ordinary pyrite; the sulphurets occur as heavy masses 5 to 6 inches thick along the vein, and a sample assayed by Prof. Charles E. Munroe contained 17.5 ounces of gold and 12 ounces of silver per ton, no free gold being visible. Pyrrhotite impregnates the country rock in the vicinity, and bronze-colored slickensides of it are seen along the vein.

THE BADGER HILL VEIN.

The Badger Hill vein, on the South Fork of Wolf Creek, 2,000 feet southwest of the Crown Point, does not crop plainly on the surface; it is said to dip to the north under the railroad; no work has been done on it for a long time. The shaft is said to be 500 feet deep, with extensive drifts; the vein spotted, but in places carrying very rich specimens.

Within this area occupied by the veins of the Idaho system there are very few veins with a north-south strike. The Morehouse, 2,000 feet west of the Maryland, dips E. 36°; it has not been shown to contain much of value. The Washington vein, 1¼ miles above the Maryland, on Wolf Creek, has been opened to a depth of about 300 feet, and is said to "show well in sulphurets and contain 3 to 4 feet of quartz."[1]

THE IMPERIAL VEINS.

About 2 miles north-northwest of Grass Valley, on both sides of Deer Creek, there is a series of strong veins with a west-northwest strike, and closely parallel to the Idaho and Orleans veins. The veins are inclosed in gabbro or in serpentine. The principal one is the Imperial, cropping in light-colored coarse gabbro on the north bank of Deer Creek. Work on this mine was prosecuted in 1883 and 1884,

[1] Mint Report, 1881.

when a shaft 280 feet deep on the incline was sunk and drifts extended east and west 350 feet. The vein is from 3 to 8 feet wide, showing some galena and free gold. This vein continues, with a slightly more northwesterly strike, toward Newtown.

THE VEINS OF GOLD HILL, MASSACHUSETTS HILL, AND VICINITY.

The veins in this locality, within the city limits of Grass Valley or a short distance to the southwest of them, were the earliest worked in this district, though but little work has been done on them in recent years. They are, in general, characterized by small width but rich ore, with frequently coarse gold. The sulphurets are subordinate both in quantity and quality. The strike is to the north, with variations to the east and west; the dip at angles of 20° to 40° either to the east or to the west. The veins lie either in granodiorite, porphyrite, or diabase, the latter two rocks being connected by transition. A strong sheeting of the country rock is sometimes apparent, as, for instance, in the western part of Main street, where the joints of the granodiorite dip to the west at 30°; this is illustrated in Pl. III, p. 104. Near the Larimer mine, on Wolf Creek, a strong sheeting, dipping 15° E., is developed in the diabase. The fissures of the veins are without doubt closely related to this sheeting and produced by the same force.

THE GOLD HILL-ROCKY BAR VEIN.

Located earliest of all the veins in this district, this vein has been worked extensively, though to no great depth, along a distance of 3,000 feet. The northern part has been opened by a number of vertical shafts to a depth of 100 to 200 feet. This northern part of the vein was worked nearly continuously from 1850 up to 1867, and is thought to have yielded $4,000,000 during that time. Between 1890 and 1893 the mine was opened again from the Gold Hill shaft, 550 feet deep on the incline, the vein dipping 28° E. Levels are turned at 290 and 540 feet, the lower extending 350 feet north and 500 feet south. It is expected that the mine will soon be reopened.

The vein crops in diabase, but all the lower workings are said to be in granodiorite. The strike of the vein, though very irregular, is north and south, and the dip 28° E. The upper portion, near the croppings, is, however, in places much flatter, and the whole hill slope is completely honeycombed by drifts and shafts. The Gold Hill vein is very irregular in width, varying from a mere seam up to 6 feet, the average being said to be 2 feet. At 275 feet south of the shaft the vein is said to have been cut off by a fault fissure, striking northwest and containing no ore. The hanging wall of the Gold Hill is strongly impregnated with pyrite. The vein is characterized by irregular pay shoots, at places being almost entirely barren, while in other places large pockets of coarse gold occur.[1] North of the Gold Hill shaft the

[1] Melville Attwood, Tenth Ann. Rept. State Mineralogist.

vein is said to split, one branch extending north and the other northeast. It is impossible to verify this at present, the outcrops not being recognizable. The gold is from 850 to 870 fine.

The Massachusetts Hill vein, worked by the old Rocky Bar deep shaft, is, beyond much doubt, on the same fissure as the Gold Hill. It was worked with short interruptions between 1850 and 1866. In 1864 and 1865 1,000 tons of ore per month were extracted for a long time, and this part of the vein is reported to have yielded $3,000,000, which, if the reports are reliable, would make $7,000,000 for the whole vein. The Rocky Bar shaft was sunk perpendicularly to strike the vein, and then followed the dip of the latter; a total perpendicular depth of 300 feet was attained. An aggregate of 2 miles of drifts is said to have been run from the shaft. In 1895, after a long period of quiescence, the vein was again opened up by a shaft in the same locality. There is but little information available as to the character of the ore and pay shoots. The latter are, however, reported to be more regular than on the Gold Hill vein. The vein crops in diabase, and only that rock has been struck in the deepest workings, as attested by the dumps, but eventually it will be found to enter the granodiorite. The gold is 855 fine.

THE SHANGHAI VEINS.

The two Shanghai veins lie from 200 to 400 feet west of the Rocky Bar, and have been opened by small perpendicular shafts. A considerable amount of rich ore has been taken from them. The gold is 860 fine.

THE BLACK LEDGE.

This vein, traceable on the surface by shafts and prospect holes, begins a short distance south of the Shanghai veins and dips to the west at angles from 50° to 30°. It has been worked only to a small depth, but is said to have produced $75,000 in the early days. The Hudson Bay shaft was sunk, in 1892, to a perpendicular depth of 185 feet to intercept the vein. At 140 feet two flat stringers were found containing coarse gold, and at the junction of these stringers with the main vein the quartz was also rich. Some of the gold occurs as big leaves inclosed in a brown opal. The main ledge is wavy and irregular in strike; the narrow pay shoots dip to the south on the plane of the vein.

THE CINCINNATI HILL, SCOTIA, AND TWILIGHT CLAIMS.

The Cincinnati Hill is also a parallel vein lying half a mile west of the Gold Hill. It has been worked on a small scale off and on since 1850, and the principal explorations were made at the north end. The Scotia shaft was sunk in 1881 on a small vein to a depth of 300 feet, but nothing of value was found. On the Twilight claim several small veins are found, dipping east, parallel to the Rocky Bar. There are also in this vicinity several veins with a northerly to north-northeasterly strike and westerly dip.

THE PEABODY VEIN.

Located just outside the city limits, this vein, whose outcrops can not now be traced on the surface, has been worked at various times,

the last time from 1890 to 1893. The northern shaft, which is the deepest, has been sunk 400 feet on the incline; the upper levels are connected with the old shaft. The vein, which dips 33° W., lies partly in granodiorite, partly in uralite-diabase. The width is said to be 18 inches on the average. The quartz of the vein contains extremely heavy and coarse gold in irregular shoots.

THE JERSEY BLUE AND HERMOSA VEINS.

These veins, located near the Watt Park, strike to the northeast and dip northwest at angles from 20° to 35°, the country rock being uralite-diabase. The latter mine is opened by a shaft 600 feet deep on the incline. The vein is said to be from 2 to 2½ feet in width, and the quartz contains some pyrite and galena. The work was chiefly done in 1892. In the following year the mine was shut down, the ore shoots not having come up to expectations.

THE DROMEDARY-GRANITE HILL VEIN.

This long vein crops in granodiorite on the east side of Wolf Creek, chiefly within the city limits, and is nearly parallel to the Gold Hill vein, though dipping in an opposite direction. The two veins will clearly intersect at no great depth. At its northerly end the vein forks, the western branch turning north-northwest through the city, and is here known as the Rock Roche vein; it is narrow, but some rich specimens are said to have been found in the croppings. South of this it is known as the Dromedary, and has been worked at various times. The vein was worked in the early fifties; again in 1863 good ore was taken out; from 1868 to 1873 it was worked with varying success by the Dromedary Company, which erected pumping and hoisting works and a 10-stamp mill. The vein is said to be from 1 to 4 feet wide, and has furnished considerable quantities of ore containing coarse gold and running from $30 to $60 per ton. The next claim is known as the Wyoming, on which in recent years a shaft has been sunk 280 feet on the incline and some high-grade ore extracted. The sulphurets are said to be very rich, containing $300 per ton. South of the Wyoming the vein is known as the Crandall, and has been worked by means of tunnels from Wolf Creek.

South of this again is the Granite Hill mine, in all probability on the same vein. The Granite Hill is developed by a shaft 500 feet deep on the incline, with drifts extended on the third and fourth levels to a maximum distance of 200 feet. Rich ore was found along the outcrops in 1850. In 1870 the mine was worked to some extent, and again opened in 1892 and 1893. The croppings are in granodiorite, but at the third level the vein cuts across the contact into diabase without any notable change. The fourth level is entirely in diabase. A dike of granite-porphyry was noted south of the shaft on this level. The vein, which dips from 15° to 30° W., is small, sometimes closing down to a mere

seam, as in the third and fourth levels south, then again opening up and containing 1 or 1½ feet of quartz. The foot wall is well defined, the hanging being more irregular. Fresh country rock often comes close to the vein. The ore in the upper levels was of a generally poor character, but in the fourth level north a pay shoot was struck, running up to a point between the fourth and third levels. The ore is high-grade, ranging up to $50 per ton. Sulphurets are very abundant, consisting chiefly of pyrite, yellow or brown zincblende, and very little galena. The gold is frequently coarse, in leaves and masses adhering to the quartz crystals, and often noted to be associated with the blende. The concentrated sulphurets are not of high grade, containing only about $60 per ton. The quartz is often crystallized, comb structure being very common, and the whole vein sometimes filled with loose bunches of milk-white crystals, often radiating from a fragment of country rock, partly replaced by pyrite. In the more compact parts of the vein druses with crystals are of common occurrence.

The Dromedary-Granite Hill vein appears to contain more sulphurets than the diabase veins.

THE ROSE HILL VEIN.

The Rose Hill vein adjoins the Dromedary on the east, but dips in the opposite direction. This vein is reported to have yielded $100,000, and a few years ago $7,000 in specimens was taken out within a small space. Recently the mine has been reopened. The shaft is 122 feet deep on the incline. The vein is from 4 to 15 inches wide.

THE VEINS IN THE VICINITY OF NEW YORK HILL AND NORTH STAR.

From the Hudson Bay shaft southward for a distance of 3,000 feet the diabase is cut by an extensive system of flat veins. The outcrops form wavy, irregular lines, and some of the veins are practically horizontal. In general the strike is east and west and the dip either to the north or, more rarely, toward the south. The veins are narrow, but frequently very rich; the pay shoots are extensive and fairly regular. The percentage of sulphurets, consisting chiefly of pyrite and galena, is small, and the gold is of unusually high value.

The red soil is deep all over this hill and the outcrops are, as a rule, only traceable by means of the old pits and shafts. On account of the flat dip of the veins vertical shafts have here been extensively used for exploitation.

THE EMMET AND IRISH AMERICAN VEINS.

The croppings of these extend in curved lines a short distance south of the Hudson Bay shaft. The Emmet dips south at 45° and the Irish American to the northeast at 35°. The Granger shaft, sunk to a depth of 200 feet perpendicularly, intersects the Emmet in the bottom, having penetrated the Irish American above.

THE NEW YORK HILL VEIN.

This vein extends with irregular outcrops southeast from the Chevanne shaft, passing south of the New York Hill shaft, where the surface croppings are strong, and thence, largely due to the steep slope of the hill, pursues an easterly direction and is believed to extend down to Wolf Creek. The strike is on the whole west-northwesterly, and the vein belongs without much doubt to the North Star system of east-west veins. The vein has been worked from the Chevanne shaft 550 feet deep on the incline, as shown by Pl. XXII, but the principal work has been done on the New York Hill ground. Located very early, the New York Hill is estimated to have produced $500,000 between 1852 and 1865. In 1866 and 1867 the mine produced $106,430 from 2,189 tons, yielding $49 per ton. The mine was then closed for several years, until 1874, when it was opened by means of a tunnel from Wolf Creek. From September, 1874, to October, 1875, the mine produced $100,000, the yield being at the rate of from $28 to $49 per ton. It is to be regretted that no maps are available illustrating the occurrence of these rich ore bodies. The mine was in successful operation up to 1883, at which time the shaft was opened to a depth of 1,300 feet on the incline, and 13 levels turned, with drifts from 100 to 1,000 feet long. The average of the ore in 1882 is given as $25 per ton. The mine shut down about 1885 and has since remained idle.

The vein is from 8 inches to 2 feet wide, encased in hard rock; the dip of the shaft is 33° NE. The percentage of sulphurets varies from 2 to 3, and the value between $80 and $100. Coarse specimen gold is of frequent occurrence.

THE NEW ROCKY BAR VEIN.

The workings on this interesting vein are fully shown on Pl. XXII, the mine having been in operation between 1880 and 1885. The sections show the existence of two flat veins dipping north and south and meeting in a curved anticlinal. A better illustration of the contemporaneous character of the two fissure systems could hardly be obtained. The New Rocky Bar produced large quantities of extremely coarse gold in 1880 and 1882, much of it being sold for the manufacture of jewelry. No data are available as to the production. The very flat "top vein" shown in the section has been worked through numerous small perpendicular shafts, and found in places to be very productive in coarse gold.

THE BOWERY VEIN.

A shaft a few hundred feet deep has been sunk on this vein, which is parallel to the North Star, and outcrops 600 feet north of it. The shaft is 900 feet east-northeast of the North Star shaft. The vein is credited with a production of $3,700 in 1869 (Raymond's reports), and about 1866 300 tons were extracted, yielding $15 per ton. The vein averages 20 inches wide (Bean's Directory).

THE INKERMAN VEIN.

This deposit, which extends a short distance south of the North Star, is not developed to any extent. It was opened in 1865 by a vertical shaft 60 feet deep and a tunnel 400 feet long; the vein, which averages 12 inches in width, has produced some beautiful specimens (Bean's Directory).

THE LAMARQUE VEIN.

The Lamarque lies about 600 feet south of the North Star and dips to the south. The vein was worked with profit for several years, but has been idle lately, until in the end of 1894, when it was opened again and yielded some ore averaging $20 per ton.[1]

THE NORTH STAR VEIN.

History.—The North Star vein, one of the most celebrated of the Grass Valley deposits, was discovered in 1851, and worked to some extent up to 1857, yielding $250,000, according to Bean's Directory. It was known in early days as the Helvetia and Lafayette, and Blake describes it under this name in 1853. In 1860 the name was changed to North Star, and it was extensively worked up to 1874, when it was shut down and believed to be worked out. During this period it produced a large amount, frequently hoisting 600 tons per month. In 1866 it yielded at the rate of $24,000 per month; in 1869 it produced $330,000; in 1870, $167,400; in 1873, $150,000; and the total product, 1860 to 1874, is probably not less than $2,500,000. After ten years of quiescence the mine was reopened, in 1884, and it has been worked continuously since. In the continuation of the shoot richer ore was met with than in the upper levels, and the production for the last years has been as follows: 1889, $413,200; 1890, $196,300; 1891, $266,000; 1892, $235,400; 1893, $335,760. The production for the last ten years amounts to between $2,000,000 and $2,500,000. The total production of the vein is thus not less than $5,000,000. In 1894, owing to reasons explained below, there was a great decrease in the production, and the mine has in the last year worked chiefly remaining ore bodies in the upper levels.

Developments.—The shaft, following the vein on the incline, has attained a length of 2,400 feet, with a vertical depth of 840 feet. The extent of the levels, as well as the direction of the shaft, is shown on Pl. XXIII. There is a 40-stamp mill on the property.

Country rock.—The vein is inclosed in a dark-green, fine-grained rock of often chloritic aspect. It is in places porphyritic by the development of small feldspar crystals, and ranges in composition from a uralite-diabase to a uralite-porphyrite, the augite being rarely preserved. Grains of pyrite, pyrrhotite, and copper pyrite occur in the rock. Only toward the west is there any indication of change in

---

[1] Nevada County Mining Review.

the country rock, as more fully explained below. The outcrops of the vein can be traced by means of the numerous little shafts on the hill to the east of the mine, for a distance of one-fourth of a mile. In the eastern part of the outcrops there are indications of a parallel vein, which is said to join the main vein at a depth of a few hundred feet.

As shown by the levels, the general strike of the vein is from west-northwest to northwest, but with many local irregularities. The dip is shown by the profile on the plate, and will average 20°, varying from 15° to 45°. The structure of the vein is well illustrated by the excellent photographs taken by Mr. E. A. Abadie, superintendent of the mine (Pls. XIII and XIV). The vein usually shows well-defined, smooth hanging and foot walls, 3 to 4 feet apart. The space between these walls is rarely if ever completely filled with quartz; a large part of it is occupied by crushed and altered country rock, and a quartz vein may lie at the hanging wall (as in Pl. XIII), in the foot wall, or, in fact, at any place between the walls. The width of the quartz does not average more than 1 foot. In places, as illustrated by Pl. XIV, the space between the walls may be practically occupied by a breccia of quartz and altered country rock. In many places within the pay shoot the walls close down to a mere seam, as, for instance, on the 2,000-foot level. Outside of the walls the diabase is but little altered by vein solution, and is often fresh and hard up to the vein. The crushed rock within the walls is greatly altered, as a rule being impregnated with pyrite and to a great extent replaced by carbonates and sericite, as shown by analysis and description on pages 149, 152. The rock below the quartz vein in Pl. XIII is entirely similar to the specimen analyzed, and the great number of veinlets shown by the photograph in the rock are all filled with carbonates, though no carbonate is contained in the main vein. A striation, horizontal or dipping slightly west, is frequently noticed on the walls. Banded structure of the quartz by arrangement of the sulphurets, as well as a sheeting due to subsequent dislocation, is quite common. Frequently, however, the quartz is massive and the sulphurets are irregularly distributed. Comb structure is apparently rare.

The ore.—The pay is almost exclusively contained in the massive quartz with sulphurets. The altered country rock between the walls contains up to a few dollars' worth of gold and is occasionally milled. The concentrated pyrite in the altered country rock contains only $15 in gold. The quartz in the pay shoot, nearly all being good ore, contains from $15 to $50 per ton, with but very little silver. Coarse gold in leafs or in bands through the quartz parallel to the walls occurs in places. The gold is unusually fine, reaching 850. The average yield previous to 1875 was $20, and between 1884 and 1894 the quartz seems to have had a higher average grade. The quartz from the cropping was very rich, and Professor Blake records in 1853 that much coarse gold occurred, and that 130 tons of quartz milled $92 per ton. The

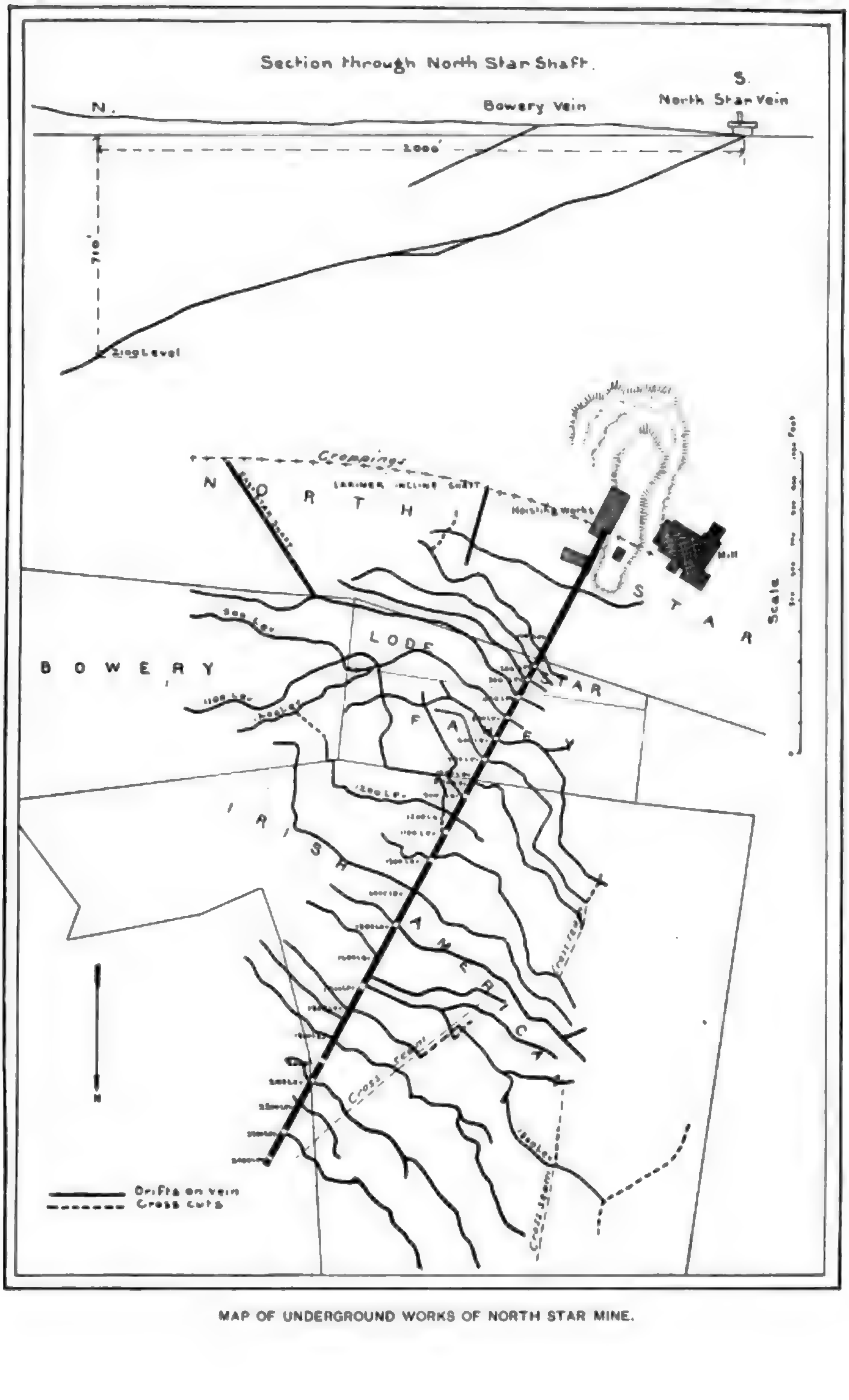
quartz contains about 2¾ per cent of sulphurets, consisting chiefly of pyrite with a little galena and hardly anything else. (For analysis, see p. 128.) The concentrated sulphurets run from $60 up to $120, and contain silver in the ratio of 0.40 ounce to 1 ounce gold. The value of the concentrates varies with the richness of the ore.

Ore shoot.—The extent of the ore shoot is well shown on Pl. XXIII, and it will be noticed that it dips to the west on the plane of the vein. Of course the whole area explored has not been equally productive, the richest portion probably being that below the twelfth level, and some levels are entirely unproductive, but considered as a whole the ore shoot is indicated by the workings.

Faults.—According to Mr. Abadie, a cross seam, striking northeast and dipping steep toward the southeast, faults the vein considerably on the seventeenth level; above this the faulting is said not to be noticeable. The fault continues, though with smaller throw, on the lower levels; on the twenty-first level it is very distinct, and the throw amounts to 16 to 18 feet along the hade of the fault. The cross seam, which does not carry any quartz, would intersect the shaft a little below the twenty-fourth level. To the west of the shaft the pay shoot has been found to end abruptly along a vertical plane laid almost due north through the collar of the shaft, and it has been supposed that the vein has been cut off by a fault, usually referred to as a crossing. There appears to be some difficulty about the proper interpretation of the facts at this place. In the eighteenth level there are, indeed, several planes, striking north and dipping about 50° W., which intersect the vein, and on the main one a horizontal striation appears. Before reaching this plane the vein splits; immediately at the plane there is no direct evidence of any great fault. West of the "crossing" the vein is replaced by a single seam without quartz; this was followed for some distance, and finally cross cuts started in hanging and foot walls. In the hanging more solid rock was met, but in the foot wall there was found a series of seams all dipping north in the crushed and altered diabase. It appears very much as if the vein along the line of the crossing had split up into a series of stringers and seams.

On the surface a short distance west of the shaft the sedimentary rocks appear, the contact running north; these clay-slates and cherts had not, at the time of my visits to the mine, been encountered in the eighteenth level, from which it follows that the contact must dip west parallel to the cross seam mentioned. It is very likely that the change in formation a short distance westward may, as Mr. H. C. Hoover thinks,[1] have caused the breaking up of the vein. The vein may appear again to the west, though the sedimentary rocks are less favorable than the diabase for a well-defined fissure; or a continuation of the pay shoot may be found in depth, the latter alternative having more probability.

[1] Mining and Scientific Press, March, 1896.



MAP OF UNDERGROUND WORKS OF NORTH STAR MINE.

THE CENTRAL NORTH STAR.

Considerable prospecting has been done toward the east to find the continuation of the North Star vein, and two shafts, indicated on the map, were sunk on the Central North Star claim. The upper shaft, 200 feet deep, struck at that depth a pretty large barren vein dipping north. The lower shaft is started at an angle of 52° from the horizontal and in a direction N. 35° W., following down a crushed zone with pyritic impregnation, but no quartz. At 400 feet a vein was struck, dipping 35° NE., and striking northwest. The rock, a normal diabase, is hard and fresh close to the vein. This vein, which is up to 1 foot wide, shows in places good prospects. It is of course difficult to decide whether these veins really are the continuation of the North Star fissure.

THE OMAHA SYSTEM.

Beginning at the Omaha mine and extending down the west side of Wolf Creek for over a mile is a series of parallel veins having many common features. They all dip to the west at moderate angles; all of them are inclosed in granodiorite; and most, if not all of them, are distinguished by rather abundant sulphurets and a percentage of silver in the sulphurets in excess of the usual amount.

THE OMAHA VEIN.

This vein is the most prominent in the system and is traceable for a distance of 4,500 feet, the most northerly outcrops appearing on the east side of Wolf Creek a short distance north of the Omaha mine, and the most southerly a short distance east of the Surprise shaft.

The Omaha and Lone Jack mines.—The Omaha and Lone Jack mines, worked by the same company, have for many years been heavy producers. The Lone Jack, located in 1855, had in 1867 a shaft 600 feet deep on the incline and was reported to have produced $500,000. The chief work on these mines was begun about 1875, and in the last years they have been steady producers. The total output is said to reach $2,000,000,[1] and in the mint reports from 1889 to 1892 they are credited with from $105,000 to $118,000. The Omaha shaft has attained a depth of 1,500 feet on the incline; the Lone Jack, located 700 feet farther south, 1,600 feet; and they are connected by drifts on most levels. There is a 28-stamp mill on the property.

The vein, which on the surface has a regular strike, develops notable curves in the strike. The dip averages 33° W. The vein forms a narrow fissure in hard granodiorite, occasionally sheeted in the vicinity of the vein. To the north of the Omaha shaft all drifts soon run into diabase. On the tenth level the diabase contact lies 20 feet south of the shaft. Diabase also appears at the shaft on the fourteenth level. Near the contact smaller dikes of white or gray, compact and flinty

[1] Nevada County Mining Review.

granite-porphyry (quartz-porphyry) are met with. The vein is said to usually become poor when incased in this rock. The tenth level extends 1,000 feet northward, some good ore occurring in it in bunches, but farther in the vein is disturbed by crossings and shows signs of splitting up.

The vein is narrow, probably averaging 1 foot, and lies between well-defined hanging and foot walls without much inclosed altered country rock. Outside of the pay shoots the vein generally closes to a seam, so that practically all quartz is good ore. The granodiorite next to the vein is impregnated with pyrite, but on the whole is unusually fresh and hard. Calcite occurs to only a limited extent in the wall or in the vein. There is very little banded or ribbon quartz, most of it being massive, with sulphurets in irregular distribution. The ore is of high grade,

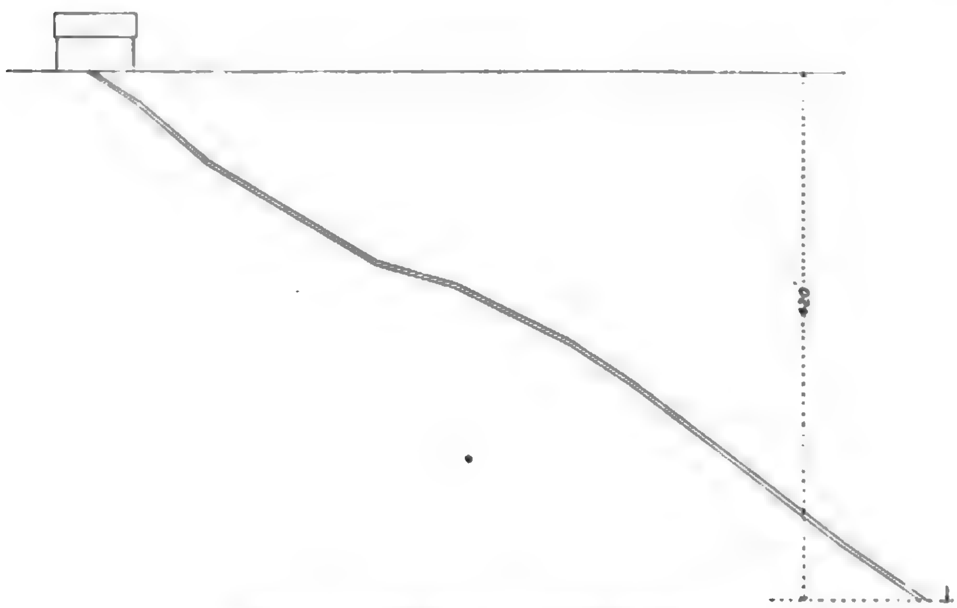


FIG. 31.—Vertical section along shaft, Omaha vein.

ranging from $20 to $30, with abundant free gold 825 to 845 fine, sometimes coarse, inclosed in quartz, galena, or pyrite; it contains 4 per cent of sulphurets, chiefly consisting of pyrite and galena, with very little blende or chalcopyrite. The assay value of the concentrates varies greatly, being from $60 up to $350. The proportion of silver in the sulphurets is great, being over 2 ounces of silver to 1 ounce of gold.

Some pay has been found to the north of the Omaha shaft, but the principal pay shoot dips to the south, beginning at the upper part of the Omaha shaft and extending toward the bottom of the Lone Jack. Very rich ore was extracted from this shoot in 1894 on the fourteenth level. Another pay shoot, also dipping south, has been found south of the Lone Jack. A strong "crossing" or barren fissure traverses the vein along the principal pay shoot, with a steep dip to the south. It does not seem to affect the tenor of the ore. On the twelfth level the vein is faulted

about 1 foot by this crossing, with a relative downthrow of the south side, and on the fourteenth level the curious relation illustrated in fig. 32 obtains at the crossing, showing a differential movement of the sheets constituting the crossing. A similar cross seam, faulting and dragging the vein, is found at the end of the tenth level north.

The Homeward Bound mine lies to the south of the Lone Jack. Only superficial developments were made up to 1867, the vein having been worked along the surface for 200 feet. The shaft at present on the property has been sunk to a depth of 350 feet, the incasing rock being very hard. Two levels are turned at 165 and 268 feet from the surface, the drifts extending a maximum distance of 350 feet southward and 750 feet northward, four distinct pay shoots having been found. The vein is said to be large. The mine was worked in 1889–90.[1]

The Hartery mine has worked two parallel veins. The old shaft is sunk on the southern end of the Omaha vein to a depth of 600 feet on

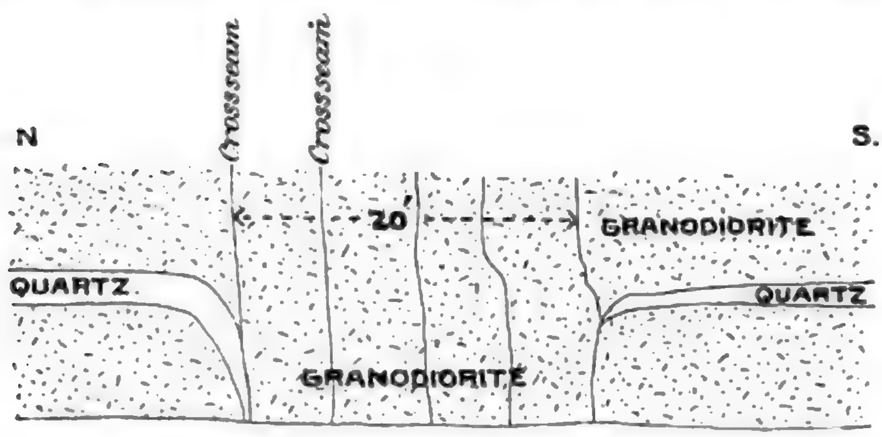


FIG. 32.—Longitudinal section, showing fault, Omaha mine, fourteenth level.

the incline. "The vein, which was located in 1853, has been worked at intervals since that time, but not more than ten or twelve years of continuous work has been spent on the property. Over $300,000 have been taken from the mine, some of the ore consisting of extremely rich specimens of coarse gold."[2] The mine was idle in 1893 and 1894. Productions ranging from $19,000 to $39,000 are credited to the mine in the United States reports for 1869, 1890, and 1891. "Three levels are turned, at 368, 508, and 600 feet, extending north a maximum distance of 300 feet and south 400 feet. A drain tunnel from Wolf Creek, 1,200 feet long, intersects the shaft 250 feet from the collar."[1]

The vein dips 30° W. and is inclosed in hard granodiorite; it averages somewhat over a foot in width. The ore is of high grade, probably averaging about $30 per ton. The amount of sulphurets is said to be small and their value $50 per ton. In the mint reports of 1890 and

[1] Tenth Ann. Rept. State Mineralogist.
[2] Nevada County Mining Review.

1891 the mine is credited with a considerable amount of silver, the relation being for the first year 1,635 ounces of gold and 871 ounces of silver.

The Hartery Consolidated shaft is sunk to a depth of 500 feet on the incline, on a parallel vein a short distance east of the Omaha vein, but comparatively little development work has been done from it. The incasing granodiorite is reported to be very hard.

THE WISCONSIN-ILLINOIS VEIN.

This is parallel to the Omaha vein, and crops a few hundred feet to the west. It was worked at its northern end from 1854 to 1856 and again from 1866 to 1870, during which time it produced a considerable amount of high-grade ore. In 1869 the old shaft was sunk to a depth of 500 feet on the incline, and the extent of the stopes is shown on fig. 33, copied from Raymond's report for 1869–70, page 47.

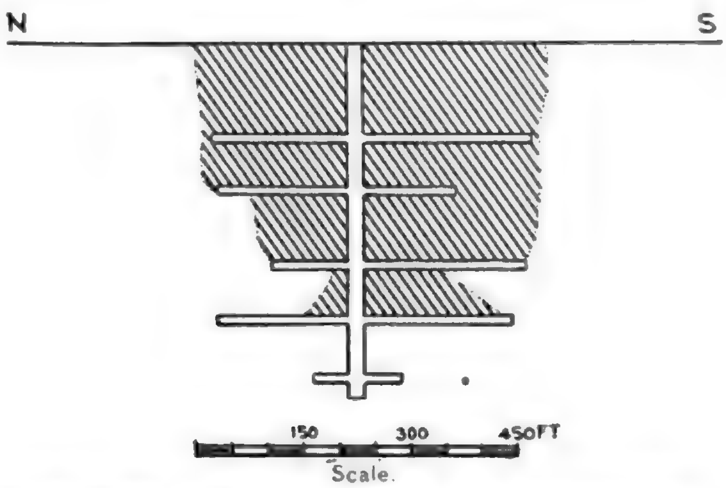


FIG. 33.—Longitudinal section, old Wisconsin mine, showing areas stoped.

In 1890 a new shaft was sunk on the vein 600 feet south of the old one; in 1894 a depth of 360 feet on the incline was attained, with levels turned at 125 and 225 feet, extending from 200 to 300 feet north and south. The vein dips W. 35°, is inclosed in hard granodiorite, sometimes showing sheeting next to the vein. The width averages 1 foot and the ore is of high grade, averaging over $30 per ton. The sulphurets, of which 4 per cent are present, average $90 per ton, chiefly in gold, and consist of pyrite, with a little galena. The gold is 854 fine. In the old shaft there was an extensive pay shoot supposed to dip to the south, and the present shaft is sunk to intercept that in depth. There are also two smaller pay shoots of high grade, one on each side of the new shaft. A cross seam cuts the new shaft without disturbing the vein perceptibly.

THE MINNESOTA VEIN.

The Minnesota vein, upon which the Surprise shaft was sunk long ago, may represent the southern continuation of the Wisconsin vein.

THE PHOENIX-MARY ANN VEIN.

This vein, located 2,000 feet west of the Allison Ranch vein, dips west from 30° to 45°. At its southern end the Phoenix shaft has been sunk on it, from which in 1870 some ore yielding $20 per ton was extracted. The developments in the northern end of the vein are slight.

THE ALLISON RANCH VEIN.

The croppings of this vein, located about 3 miles south of Grass Valley, on the west bank of Wolf Creek, are quite inconspicuous and can not be traced either south or north of the shaft. The vein was accidentally discovered in 1854 by sluicing on the croppings. From that time up to 1866 the mine was worked continuously, producing 46,000 tons of ore, yielding $2,400,000. In 1863 the mine became poor, but the following year rich quartz was again found. The product for the three years ending December 30, 1865, was $1,000,000, and $200,000 were produced in 1866; the operations were suspended in September, 1866, and the mine has remained idle ever since. The shaft is sunk on the vein to a depth of 500 feet on the incline, the lowest level extending 220 feet north and 214 feet south. A portion of the quartz on this level was very rich, but the greater part was barren. There seems to have been no adequate reason for abandoning the mine without further exploration. The vein strikes N. 5° to 15° W., and dips 40° to 45° W. Phillips gives the width as 2½ feet, while Bean's Directory states it to have been from 14 to 18 inches in the lowest level, where the vein was in part considerably broken up. There is a clay parting on the hanging wall, while the foot wall is without any distinct clayey division from the quartz. Phillips states that the average yield on the lowest level was as good as that from the upper part of the mine. Near the surface the decomposed ore was extremely rich; Mr. Melville Attwood milled 21 tons in 1855 which yielded $370 per ton.[1] The average of the ore from the deepest levels was also high. The quartz was in places extremely rich; between these bunches some quartz was found that would hardly pay expenses. There was a considerable percentage of sulphurets, chiefly pyrite, but also galena and chalcopyrite; rich silver minerals were found in a specimen from the Allison Ranch vein (see p. 119).[2]

While the Allison Ranch can not be traced far on the surface, there appears on the hill to the south several veins striking north-south and opened by small prospect holes. There is in places considerable sheeting of the granodiorite, the sheets dipping west. Large outcrops show on top of the hill south-southwest of the Allison Ranch, and on the steep slope eastward are several small veins, showing some quartz with much pyrite.

[1] Eighth Ann. Rept. State Mineralogist, p. 777.

[2] Notes chiefly from Bean's Directory, J. A. Phillips's Mining and Metallurgy of Gold and Silver, and Ross Browne's report for 1868.

OTHER VEINS.

Almost due north of the Allison Ranch shaft, a distance of 1,500 feet, is the Franklin vein, on which in early days considerable work was done and a large mill once erected.

The Allison Ranch Ford–Horseshoe vein is located on the west bank of Wolf Creek and probably is a continuation of the Franklin or an adjoining parallel vein. The Horseshoe shaft is 3,500 feet north of the Allison Ranch and 240 feet deep on the incline. The vein is from 10 to 20 inches thick.

THE FOREST SPRING GROUP OF MINES.

Four miles south of Grass Valley and 1¼ miles south of Allison Ranch there is, on the east side of Wolf Creek, a series of veins of some importance.[1] The ores are similar to those of Osborne Hill.

THE NORAMBAGUA VEIN.

The Norambagua was worked extensively between 1855 and 1867. Its total production is said to amount to $1,000,000 (Bean's Directory).

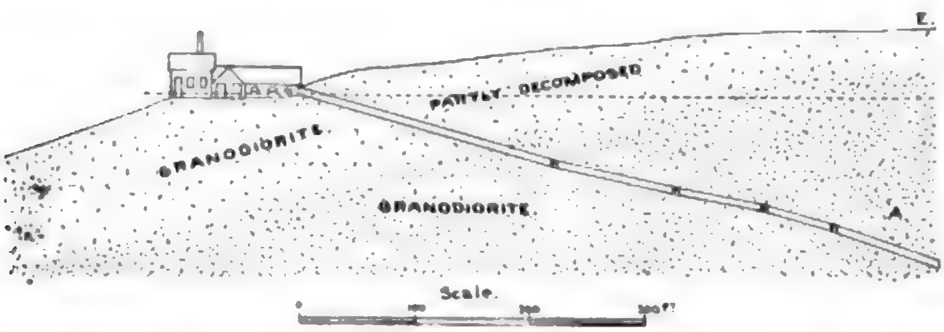


FIG. 34.—Vertical section along shaft. Norambagua vein. After Melville Attwood in Phillips's Metallurgy of Gold and Silver.

In 1866 the production was $80,000. The mine was reopened for a short time in 1892 and is credited with a production of $2,500 in that year. During the principal period of exploitation the cost of mining and milling was $30 per ton. This very high figure is evidently due to the narrow character of the vein. The incline is 567 feet long down to the fifth level, attaining a vertical depth of 120 feet at that level. The levels extend 1,000 feet south and 500 feet north from the shaft, and a drain tunnel joins the shaft 490 feet from the croppings. The Norambagua has a northerly strike and a dip of 15° E., thus belonging to another system than the Omaha. It is contained in a blocky granodiorite and is very narrow, rarely over 10 inches wide and more frequently 4 or 5. The ore is a bluish quartz, seamed and banded with pyrite and arsenopyrite arranged in parallel zones, producing a ribbon-like structure. The gold is rarely visible to the naked eye. The tenor of the ore is from $40 to $100 per ton, and frequently about $65 per ton (Phillips).

[1] See Geologic Atlas of the United States, folio No. 18, Smartsville, Cal.

There are 1.33 per cent of sulphurets, according to Phillips. Bean's Directory gives 3 per cent. These are rather low grade, being said to average $50.

The Bourbon veins lie 500 feet west of the Norambagua, and the Shamrock 1,200 feet southeast of it.

THE PERRIN OR SLATE LEDGE VEIN.

For many years this vein has been worked intermittently and has been a considerable producer. In the reports it is credited with $32,000 in 1869, $5,000 in 1890, and $13,100 in 1891. It was actively worked in 1893 and 1894. The vein is opened by an incline shaft started in the tunnel from Wolf Creek, 900 feet from its mouth, the total length of the tunnel being 1,800 feet. The incline is sunk 300 feet on the vein, which strikes east and west and dips 30° S. The country rock is chiefly diabase with some clay-slate, but the vein crosses the granodiorite contact 1,600 feet from the mouth of the tunnel. The ore ranges from $15 to $20 per ton, the gold rarely being coarse and averaging 745 fine. The sulphurets, of which there are 3 per cent, consist chiefly of arsenopyrite and contain about 3.25 ounces of gold to 2 ounces of silver per ton. On the tunnel level the pay shoot is continuous for 1,000 feet, and large quantities of ore have been stoped above it. Below the tunnel level the shoot appears to split into several branches inclining to the west, contrary to the usual rule for veins dipping south.

VEIN SYSTEMS OF PENNSYLVANIA, W. Y. O. D., AND THE WESTERN FOOT OF OSBORNE HILL.

GENERAL FEATURES.

The hills to the southeast of Grass Valley, usually referred to as the Kate Hayes and Ophir hills, are in an unusual degree shattered by jointing or sheeting, and numerous quartz veins are found parallel to these systems of dislocation. The most prominent vein system dips west at moderate angles, but there is also ample evidence of the existence of another system dipping east at about the same inclination, and there is excellent evidence of the contemporaneous formation of the two systems. The veins dipping east are best represented in the continuation of the system to the south-southeast near the southern limit of the sheet. The deposits lie chiefly in granodiorite, near the contact, while some of them are contained in the diabase. The gold is generally of high value, often coarse; the sulphurets are moderate in quantity; arsenopyrite is not generally present.

Exceptional veins are the nearly perpendicular Golden Treasure, striking north-northeast, and the Little Diamond, which dips 45° S.

KATE HAYES VEIN.

Located on the summit of Kate Hayes Hill, 4,000 feet south of the Grass Valley post-office, this vein was worked considerably thirty years

ago, as is indicated by the pits along the croppings. The total production is said to have been $125,000, and the ore contained from $35 to $50 per ton.[1] On the summit of the hill is a shaft 300 feet deep on the incline, on which work was resumed in 1895 under the name of Hecla mine. The vein dips 45° W. and is inclosed in hard granodiorite.

THE CRESCENT VEIN.

The Crescent vein is located 600 feet east of the Kate Hayes, and dips to the east.

THE PENNSYLVANIA VEIN.

A few hundred feet farther west the Pennsylvania vein is met with. The vein has been exploited at various times and produced a large total amount. Work of development has been going on for the last five years, and in 1894–95 a considerable amount was produced.

The vein, which is inclosed in granodiorite, can be traced on the sur-

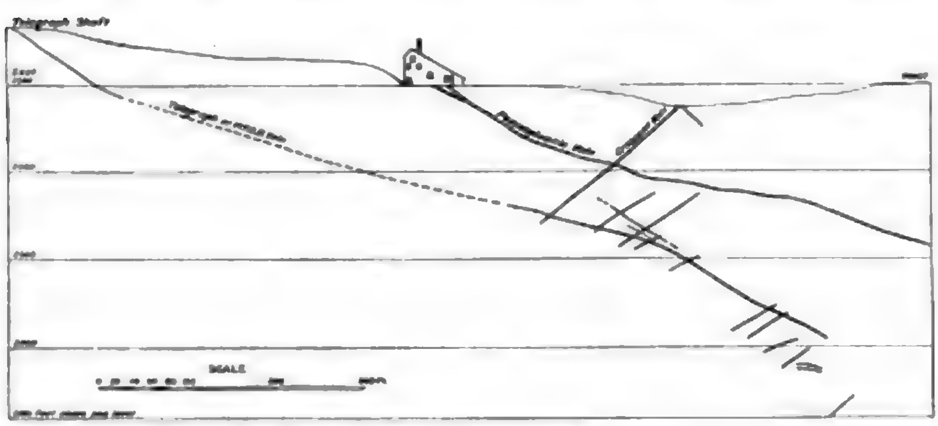


FIG. 35.—Vertical section along shaft, showing veins and cross fissures, in the Pennsylvania mine.

face for 1,000 feet north of the shaft, while to the south the continuity of the surface croppings is doubtful. The shaft is sunk to a depth of 600 feet on the incline, the vein dipping west at an average angle of 20°. A part of the shaft, continued down at a steeper angle, struck a parallel vein believed to be the Telegraph, though this would necessitate a a very flat dip for the latter. The vein averages a little less than 1 foot in width; the ore carries frequently coarse gold and a small percentage of pyrite and galena. The wall rock is generally fresh, or at least not extensively altered. The sheeting and fracturing are very extensive and render the work of exploitation very difficult; the vein frequently pinches to a mere seam, difficult to follow. The system of fissures dipping east is very prominent; at 220 feet on the incline the Crescent vein intersects the Pennsylvania, and throughout the mine there is a constant tendency of the main vein to throw out stringers dipping east. These relations are illustrated in fig. 35. Besides, there

[1] Nevada County Mining Review.

is a system of "crossings" or barren seams striking northeast, usually dipping southeast at steep angles. Most of these crossings appear south of the shaft, and at least one of them throws the vein on the fourth level 90 feet (measured along the drift) in the foot wall—that is, produces a normal fault with a relative downthrow of the south side. The crossings contain no quartz and afford excellent conduits for the subterranean circulation of water.

The largest ore bodies were found north of the shaft between the first and third levels. The ore body then appeared to be cut off, but the apex of a new shoot was found on the fourth level south of the shaft. On the whole, the ore shoot thus dips to the south on the plane of the vein.

THE W. Y. O. D. VEIN.

Only in the last few years has this vein entered the ranks of the large producers. Long known on the surface as a small 3 to 6 inch vein, it rapidly developed strength as depth was attained. The production for the four years from 1890 to 1893 was, respectively, $26,000, $53,500, $108,700, and $143,360. The shaft is at present 1,400 feet deep on the incline, drifts extending a maximum distance of 700 feet south and 600 feet north.

The vein, which dips 32° W., can be traced in the granodiorite up to the Telegraph mine, where a small shaft 175 feet deep on the incline was sunk on it in 1892. South of the W. Y. O. D. it enters the diabase and turns more southeasterly, the vein at the same time attaining a steeper dip. In Little Wolf Creek the exposures are not satisfactory, but the vein cropping on the ridge to the south of it and opened by a tunnel 700 feet long, indicated on the map on the south side of the ridge 2,500 feet south of W. Y. O. D. mine, may be the continuation of this vein. In the tunnel this vein is nearly perpendicular and 2 feet wide. The relation of the granodiorite contact on the surface and on the plane of the vein is shown in fig. 36, accentuating the wholly irregular surface separating the two formations. On the eleventh level the contact was crossed, and the deepest parts of the mine are now in granodiorite. The contact is generally sharp; in places light-colored granite-porphyry (quartz-porphyry) is met with near the contact.

The vein is generally narrow, occasionally reaching 2 feet in width, and sometimes closing down to a seam. A little calcite sometimes occurs close to the vein in the country rock, which is much fractured and impregnated with pyrite. Cavities filled with quartz crystals are common on the vein. The ore consists of quartz with finely distributed gold, 806 to 832 fine. The sulphurets, of which there are 2 per cent, consist of pyrite, galena, and blende, with a little arsenopyrite in places. The sulphurets contain from 2.5 to 4.5 ounces of gold and 5 to 8 ounces of silver per ton, the richest being the galena from the fine slimes. The sulphurets from the altered country rock adjoining the vein contain only from $6 to $12 per ton. The general tenor of the ore

is high, ranging from $20 to $50 per ton. The ore shoot, which was narrow in the upper part of the mine, rapidly widened between the sixth and ninth levels, attaining a maximum length of 850 feet; below this it showed a lower grade of ore for some distance, and then improved again greatly. The shoot, though very irregular in its details, dips on the whole to the south on the plane of the vein. Thus far the largest ore bodies have been found in the diabase. There are a number of seams dipping east, as in the Pennsylvania, and there is a tendency of the vein to fall back in the foot wall on these seams. A great number of "crossings," or barren seams, follow the ore shoot down, with a general southwesterly strike and steep or vertical dip; they do not appear to throw the vein to any noticeable extent.

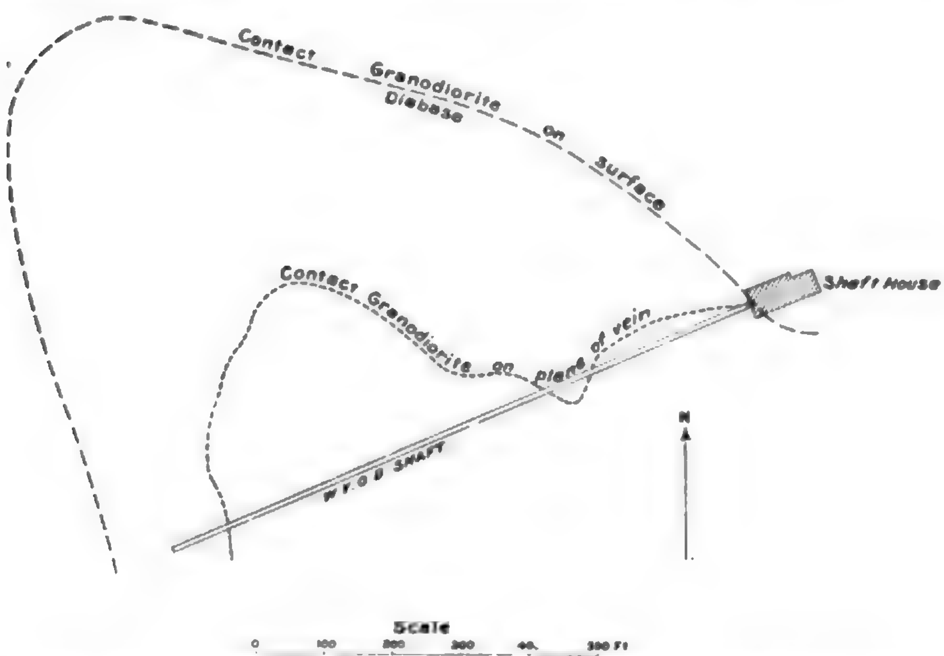


FIG. 36.—Horizontal projection of contacts on surface and on plane of the vein, W. Y. O. D. mine.

OTHER VEINS.

Closely parallel to the W. Y. O. D., in strike and dip, are the Parr, Cassidy, and Linden veins, on which only a small amount of development work has been done.

The Golden Treasure shaft was sunk 180 feet perpendicularly to cut the W. Y. O. D., which, however, it failed to do, the vein here having assumed a steep dip. A cross vein 2 feet wide, and nearly perpendicular, outcrops just west of the shaft.

THE DIAMOND, BULLION, AND ALASKA VEINS.

Following the western foot of Osborne Hill, there are a number of veins with an easterly dip of about 45°. It is very likely that they may in reality be one continuous vein with a general north-northwest

strike, but the outcrops can not be continuously followed. The Big Diamond vein outcrops for a few hundred feet 3,000 feet due east of the Omaha mine. It has been opened by a tunnel and small shaft, and in former years (1869 to 1872) a considerable amount of ore, averaging $20 or more per ton, has been extracted from it. The vein is said to be 2 feet wide.

The Little Diamond is a cross vein dipping 48° S. and containing a shoot of ore dipping to the west on the plane of the vein. It is opened by a shaft 290 feet deep on the incline, but no work has been done on it in recent years.

The Galena and Bullion vein was worked at its northern end, known as the Ione or Galena, in 1865, by a vertical shaft 140 feet deep. The vein is 1 to 4 feet thick, the ore averaging $20 (Bean's Directory). The gold is 815 fine. On the southern part the Bullion shaft (formerly known as the "Union Jack") has been sunk to 400 feet perpendicularly, with drifts aggregating 500 or 600 feet. The production is reported to be $500,000, the width 1 to 4 feet, and the ore to contain $8 to $50 per ton. It has been idle for a long time.[1]

South of the Bullion lies the Alaska shaft, sunk 100 feet perpendicularly, then for 400 feet following the vein. South of the Alaska the vein bends to the southeast and enters the diabase area. The Lebar, or Presqu'isle, 1,500 feet south of the Alaska, belongs to the same system, and has yielded some good ore from a 1-foot vein.

THE FRANKLIN AND OTHER VEINS.

The Franklin is located east of the Alaska, higher up on the hill; it has been worked intermittently by means of tunnels and a small incline, and yielded a considerable aggregate sum. The vein lies chiefly in decomposed diabase, but its northern end cuts into the granodiorite. The dip is 35° W. The ore is of high grade and is rich in sulphurets, the gold being 808 fine.

In the lower part of the ravine emptying into Wolf Creek due east of the Wisconsin mine, called Little Diamond Ravine, two veins are found—the Snowpoint, opened by a tunnel 500 feet long, and the Portland, a strong vein outcropping on the side hill east of the ravine. The Portland is said to be 4 feet thick and rich in sulphurets, and has produced some ore of medium grade.

THE EMPIRE-OSBORNE HILL VEIN SYSTEM.

This complex of veins, extending for nearly 3 miles with a general direction of N. 17° W., forms an excellent example of a "Gangzug," or system of "linked veins." The veins lie throughout in diabase, diabase-porphyrite, or porphyrite-breccia. The dip is always to the west, averaging 35°. In spite of this general similarity the ores are not identical throughout. From the Orleans mine southward the eastern

[1] Nevada County Mining Review.

part of the system contains a lower grade of gold and is particularly distinguished by a considerable percentage of arsenopyrite. There are two main branches—the Rich Hill and the Ophir Hill, the latter being the more extensive. Both join at the Magenta mine, and beyond this point appear to break up into stringers. The Magenta shaft is sunk on the vein just north of the junction to a depth of a few hundred feet on the incline. The mine was worked on a small scale at different times up to about ten years ago. "Between the second and third levels a vein known as the Mohawk intersects it at right angles."[1]

THE EMPIRE MINE.

The Empire enjoys the distinction of having been worked more nearly continuously than any other mine in the district, having been in operation with but short interruption from its discovery in 1850 to the present time. Between 1852 and 1864 it is reported to have produced $1,000,000, and from 1864 to the close of 1866 the output was $300,000. In 1866 it produced 1,200 tons per month. In 1869 the output was $349,000; in 1870, $240,000; in 1873, $240,000; in 1874, $187,000; in 1875, $232,000; in 1889, $35,500; in 1890, $73,100; in 1891, $103,000; in 1892, $82,000; in 1893, $110,800. The total production is probably in the vicinity of $6,000,000.

The Empire has a shaft 2,400 feet deep on the incline on the Ophir Hill vein, as well as a smaller shaft on the Rich Hill vein. The drifts on the main vein extend to a maximum length north 1,500 feet and south 700 feet. A 40-stamp mill reduces the ore. The vein carries a large amount of water, the cross seams carrying it down from the whole hill. The outcroppings of the vein lie entirely in a fine-grained diabase, but at or near the eleventh level the vein cuts across the contact into the granodiorite. These upper workings are not accessible now. Smaller dikes of granodiorite were noted on the fifth and seventh levels.

The vein has a northerly strike, changing in the southern part of the mine to north-northwest, with many curves and local irregularities, the dip, which is fairly regular, averaging 24° W. The vein is narrow, usually from 10 to 18 inches wide, and in structure is very similar to the North Star vein. There are usually two distinct walls, 3 to 4 feet apart, with quartz vein in the hanging or foot, or both, and seams also traversing the altered country rock separating the walls. (See Pl. XV.) Outside of the fissured zone the diabase is fresh and hard, while within it is usually extensively altered by carbonatization and traversed by seams of calcite. Occasionally small open fissures are found in it coated with calcite crystals. It is also usually impregnated with pyrite, and this replaced country rock, when found near rich quartz, may contain two or three dollars in gold per ton. Gold has been observed to occur occasionally inclosed in the decomposed country rock. The ore

[1] Mint report, 1883.

consists of quartz with often coarse, free gold 805 fine. The quartz is partly ribboned, partly massive, and contains 3 per cent of sulphurets, chiefly pyrite, with little galena and occasionally blende and chalcopyrite. Arsenopyrite is absent. The concentrated sulphurets contain from 3.5 up to 5 ounces of gold and about 2 ounces of silver. Large parts of the pay shoot have averaged $30 to $50 per ton. The main pay shoot extends on both sides of the shaft and is somewhat irregular in shape, though it is stated that the richest ores are from shoots dipping south on the plane of the vein. The greatest length of stoped ground is 2,000 feet. On the thirteenth level the vein is split into three parts, the division extending several hundred feet north and south. This break, occurring in the main shoot, made the exploitation very difficult and diminished the tenor of gold in the veins. Excellent ore 18 inches wide was, however, stoped on the twentieth level north in 1894. The distance between the branches makes it doubtful whether they will join again in depth. Several strong cross seams run through the northern part of the mine, and have been observed to fault the vein a little. The relations illustrated in fig. 37 were shown in the stopes a little below the twentieth level.

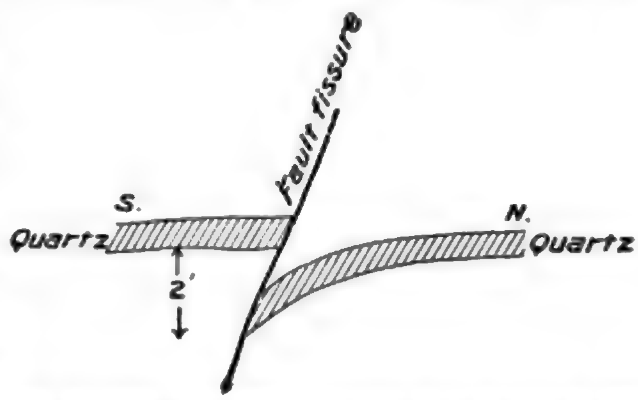


FIG. 37.—Longitudinal section, showing fault, Ophir Hill vein, twentieth level, Empire mine.

The Rich Hill vein, dipping 30° W., and approaching the Ophir Hill in depth, has been opened to a less extent by an incline shaft and by means of a crosscut from the sixth level on the Ophir Hill shaft. Good ore was stoped from this vein in 1894 on the so-called Rush and Laton shoot, which is said to be 200 feet long. For some distance above the sixth level the vein is divided in two, joining again above the fifth level. The hanging vein is the better, showing about 12 inches of massive quartz with pyrite and galena, and is inclosed in diabase, hard and fresh close up to the vein. This complete absence of crushed or altered wall rock is somewhat unusual. Brown opal containing coarse gold has been noted from this shoot.

The Rich Hill continues southward through New Ophir and Daisy Hill claims, on which the developments are not extensive. A shaft, 300 feet on the incline, was sunk on the latter many years ago, and the mine is reported to have been reopened in 1895. A branch vein is said to connect with the Ophir Hill vein at the Prescott shaft.

THE ORLEANS MINE.

The Ophir Hill vein doubtless continues southward toward the Orleans mine, though the croppings do not show quite continuously on the surface. The old Orleans shaft was sunk to a perpendicular depth of 100 feet; the new shaft, started a few years ago, inclines 35° W., the croppings lying some distance east of the shaft. The depth is 325 feet, with drifts at 200 and 280 feet. A considerable amount of ore has been produced by the Orleans. The gold is 790 fine. There are 3 per cent of sulphurets, averaging 3.5 ounces of gold and 0.7 ounce of silver. The vein continues southward by Mayflower, Prescott, Betsey, and King Hill shafts, all worked to some extent many years ago. King Hill and Prescott shafts were sunk to a depth of 300 feet on the incline. The long Orleans tunnel drained the surface workings as far south as the Betsey mine. This narrow vein appears to have been characterized by a strong percentage of arsenopyrite and rich ore.

HEUSTON VEIN.

Lying parallel with the Ophir Hill vein and several hundred feet east of it is the Heuston, which can be traced only 1,500 feet on the surface. The deep explorations on this vein began in 1861 and were continued until about 1870, since when the mine has been idle. The shaft is 300 feet on the incline, dipping 25° W., and the several levels extend north and south. The vein is very narrow, averaging 8 inches, inclosed in hard diabase, but very rich. It yielded $500,000 between June, 1864, and April, 1867. Some ore containing $160 per ton was mined in 1867. The expenses were estimated to have been $45 per ton in 1867.[1]

THE SEBASTOPOL VEIN.

At a distance of 600 to 700 feet east of the south end of the Ophir Hill lies the Sebastopol, also dipping west at 35°. The Sebastopol shaft was worked 180 feet on the incline between 1856 and 1858, yielding $200,000, and was again opened for a short time in 1880.

The southern end of the vein has recently been opened by the Electric shaft, sunk to a depth of 400 feet, dipping 30° W., and with drifts extending 150 feet north and south. South of the shaft the vein turns to the southwest. The country rock is a diabase-breccia; the vein is 1 to 2 feet wide, and the ore carries finely divided gold with pyrite and some arsenopyrite and galena. On this and adjoining veins the pay shoots trend rapidly to the south on the plane of the vein. Two smaller veins, which have been worked to some extent and proved to pay well, lie between the King Hill and the Electric, the Sanders on the east and the Payday on the west.

[1] Notes from Bean's Directory.

THE OSBORNE HILL VEIN.

General features.—Beginning a short distance west of King Hill shaft, the Osborne Hill vein can be traced half a mile south-southeast to beyond the Centennial shaft. On the east side of Osborne Hill there are no outcroppings for 3,000 feet, when again a vein appears which possibly may represent the extension of the Osborne Hill, having the same direction of strike and dip and the same characteristics of ore. Very little work has been done on this southerly extension.

The Osborne Hill mine.—The principal developments are found at the Osborne Hill mine. From 1852 to 1857 the vein yielded large returns from the surface ore, the stopes extending 100 to 180 feet on the incline for 200 feet south of the shaft and 800 feet north. Between 1865 and 1870 the main shaft was sunk to 400 feet and much ore was extracted. The mine was idle from 1870 to 1894, when it was opened again, the shaft sunk to 600 feet on the incline, the drifts extended, and a 20-stamp mill erected.

The character of the wall rock varies somewhat; it is in part a very fine grained uralite-diabase, in part a hornblende-porphyrite or a breccia of porphyrite and brownish argillite or fine-grained sandstone.

The vein strikes north-northwest with many local curves and irregularities, and the dip varies from 29° in the upper levels to 44° in depth. In some parts, as on the fifth level north, the vein runs down to a seam, which, though containing rich ore, is too small to work. The main ore body was exposed on the fifth level north, which shows excellent ore 3 to 4 feet wide and said to average $30 to $40. The foot wall is well defined, the hanging less so. The vein makes less the impression of a continuous open space filled with quartz than of a zone of crushed rock 1 to 3 feet wide, containing many smaller open fissures and spaces subsequently filled with quartz. Comb structure and vugs filled with crystals are very abundant. Banded structure by deposition and ribbon structure by subsequent sheeting both occur. The country rock between and adjoining the walls is very much decomposed and chiefly converted into sericite, there being but little carbonates. It is, besides, filled with arsenopyrite in small crystals. In the quartz free gold is rarely visible. The ore contains arsenopyrite, with some pyrite and a little zincblende, galena, and occasionally chalcopyrite, in all 1¾ per cent sulphurets. The brown blende occasionally contains coarser gold. The gold is 767 fine; the sulphurets contain very little silver.

In a few places there are indications of a system of joints dipping 30° E. Several crossings cut the vein without faulting it, and have an easterly strike and a steep dip north or south. Occasionally the cross seams carry some quartz, and in one instance tetrahedrite was found on one of them.

A branch vein with steep dip, called the Shoofly, lies to the west of the Osborne Hill mine.

The Centennial mine.—South of the Osborne Hill mine probably the same vein is worked by the Centennial shafts. This mine was worked between 1876 and 1883, producing a reputed total of $600,000. In 1893 work was resumed on the new shaft, but soon stopped again. There are two shafts; the old one is several hundred feet deep, and the extensive dumps indicate that a great amount of work has been done from it. The new shaft, 300 feet farther south, is 650 feet deep on the incline. The vein dips W. 30°, and is contained chiefly in porphyrite-breccia with many brownish fragments of sedimentary flinty rocks. The quartz, which averages 1 foot in width, contains finely divided gold and a considerable amount of sulphurets, chiefly arsenopyrite, with much pyrite and a little galena. Calcite, in large cleavage pieces, is frequently found in the altered country rock adjoining the vein. The pay shoot is said to be 250 feet long, rapidly trending south on the plane of the vein. One or two cross seams cut the vein without faulting.

THE LAFAYETTE AND COMET VEIN.

Extending diagonally across Osborne Hill, with a strike a little west of north, this strong vein can be traced for a distance of 1½ miles. Comparatively little work has been done on it. At its northern end the Conlan shaft was sunk 190 feet on the incline in 1892, disclosing a vein of 26 inches and some good ore. The vein dips 42° W. and is inclosed in porphyrite-breccia. Between the Conlan and the Lafayette tunnels the outcrops are not very distinct, but south of the latter mine they can be traced easily. In the Conlan there are said to be two ore shoots pitching southwest.

The Lafayette tunnel strikes the vein 450 feet from the mouth, and drifts are extended on the vein 80 feet north and 500 feet south. The vein dips 25° W.; the ore is ribboned quartz with pyrite and galena, and contains $20 to $50 per ton.[1]

The Comet tunnel, farther south, cuts the ledge 600 feet from the mouth, and a considerable amount of ore has been stoped at various times.

At the southern end there are two strong veins on the Indiana claim; on the more westerly of these a perpendicular shaft has been sunk 80 feet deep.

THE VEINS OF ROUGH AND READY AND DEADMANS FLAT.

In the vicinity of Rough and Ready, 4½ miles west of Grass Valley, there are several smaller veins, usually rich in pyrite and other sulphides.

The Osceola vein, inclosed in amphibolite, striking east-west and dipping 60° N., has been developed by two tunnels and a small shaft. The *Ironclad*, in gabbro, 5 miles west of Grass Valley, dips 45° W., and is opened by a 200-foot inclined shaft. The ore is strongly sulphureted,

[1] Eleventh Ann. Rept. State Mineralogist.

containing about $20 per ton. The vein is said to be 2 feet wide and was worked to some extent in 1881.[1]

Deadmans Flat is situated 3½ miles to the west-southwest of Grass Valley, on the rolling plateau extending in that direction. The surface gravels in the gulches of this vicinity were extremely rich in coarse gold, and several promising quartz mines have been found there. The veins, which are indicated on the Smartsville sheet,[2] lie in the mostly massive, rarely schistose, amphibolite area between two masses of gabbro. The grain of the rock, which is chiefly of dark color, varies greatly, and in places unaltered diorite or gabbro is found. The whole area appears to be a partially dynamo-metamorphosed complex of diorite and gabbro. The veins form three groups, with a generally northerly strike, and generally dip west. On the north lie the South Star claims, followed southward by the California mine, also known as the Pittsburg. This vein, which dips WNW. 65°, has been worked at intervals, and at times has been a considerable producer. The shaft is 280 feet deep. The ore contains coarse gold, 5 to 10 per cent of sulphurets, and a total of from $40 to $75 per ton. The vein is said to average 1 foot in width. It is credited with 250 tons of ore in 1875, producing $20,000, and with $16,000 in 1891. The total production is not known.

The Seven-thirty vein, one-half mile south of the California and dipping 55° W., extends through two locations. It has been worked at various times by two incline shafts 200 feet deep. The vein is 18 to 24 inches wide, and has produced a notable amount of ore. The surface ore has been worked for several hundred feet. The ore is white quartz with but little sulphurets, and is said to average $20 per ton in the shoots. The superintendent states that the fineness of the bullion exceeds 900, which certainly is most unusual. The mine is credited with $11,200 in 1869. In 1893, 300 tons were crushed, yielding $6,000.

The Normandie veins are located 1 mile east of the Seven-thirty, strike a little west of south, and dip 40° W. The shaft is 120 feet deep. The two veins, 40 feet apart, average 6 inches in width, but contain very high grade ore. A cross vein, called the West Normandie, dips 35° N.

---

[1] Mint reports.

[2] Geologic Atlas of the United States, folio No. 18, Smartsville, Cal.

CHAPTER XVII.

SUMMARY.

INTRODUCTION.

The mining districts of Nevada City and Grass Valley are situated in Nevada County, 135 miles northeast from San Francisco, on the western slope of the Sierra Nevada, at an elevation of about 2,500 feet.

A great number of important gold deposits, consisting of quartz veins and gold-bearing gravels, are concentrated in this vicinity.

The districts were discovered in 1849 and the mines have been worked continuously since that time. At present the quartz-mining interests are by far the more important. The districts are estimated to have produced a total of about $113,000,000. During the last years the Grass Valley district has annually produced an average of $850,000 and the Nevada City district $400,000, all in gold; the silver production is comparatively insignificant.

GEOLOGY.

Distinction is made between the Tertiary and Recent rocks, called the *superjacent* series, and the pre-Tertiary rocks, called the *bed-rock* series. The latter contains the quartz veins, the former the placer deposits resulting from the disintegration of the veins. The districts lie at the border line between the foothills of igneous rocks and the middle slopes of sedimentary formations of Jurassic or older age. The rocks prevailing in the vicinity are chiefly of igneous character. Only a few areas are of sedimentary origin, and consist of siliceous argillite, slates, sandstones, and schists of partly Jurassic, partly Carboniferous age. They are generally altered, but rarely so much that their origin can not be recognized. The igneous rocks consist of granodiorite, diorite, gabbro, pyroxenite, peridotite, diabase, and porphyrite. By metamorphic processes amphibolites have in places been formed from the diorite, gabbro, diabase, and porphyrite, while the pyroxenite and peridotite often have been changed to serpentine. The igneous rocks are of Juratrias or later age, with the possible exception of the diorites, gabbros, and peridotites. Beginning with the latter, the eruptions were continued by the diabases and porphyrites and closed by the great intrusions of granodiorite of probably early Cretaceous age. The period of maximum intensity of volcanic activity appears to be contemporaneous with or a little later than the close of the Jurassic.

The oldest sedimentary rocks were folded and compressed before the igneous activity had commenced. After the close of the Jurassic a second folding and compression took place, which metamorphosed many of the igneous rocks just erupted. Subsequently to the intrusion of the granodiorite the metamorphosing influences have been slight, but the range was subjected to great compressive stress, producing systems of joints and fissures on which the quartz veins were formed.

In discussing the metamorphic processes, distinction is made between dynamo-metamorphism, dynamo-chemical metamorphism, common hydro-metamorphism, hydro-thermal metamorphism, contact metamorphism, and weathering, all of which are shown in this vicinity. The different ways in which pyrite and pyrrhotite may form are described; also the course of the alteration in the feldspars, which chiefly are converted to micaceous products, and possibly scapolite, but not extensively to kaolin.

THE FISSURE SYSTEMS.

The compressive stresses to which the range was subjected after the intrusions of granodiorite produced joint systems in different directions, traversing all rocks of the bed-rock series. Sometimes the joint plates are thin and a sheeting of the rock is produced; at other places the spacing was much larger and a series of parallel fissures was produced. The fissure systems may be divided into north-south veins dipping either east or west at moderate angles, averaging 35° or 40°, and the several groups of east-west veins dipping either north or south at high or low angles. Each direction of strike has its two directions of symmetrically opposite dip, which are referred to as *conjugated* systems. The faults on the veins are in general small, but on the Merrifield and Ural veins great movement has taken place, resulting in a throw of probably over 1,000 feet measured along the dip of the vein. Nearly all faults recognized are overthrusts. The north-south veins are older than most of the east-west veins and are faulted by them. It is further shown that the fissures cross the contacts without being influenced by them, except as the susceptibility to deformation and breaking of different rocks is concerned.

The origin of the fissure systems is shown to be compressive stresses, which will, as indicated by experiments, produce such conjugated fractures as are observed here.

PRODUCTS OF VEIN FORMATION.

The products of the vein-forming agencies are:

1. Quartz with native gold and metallic sulphides. This is formed by deposition in open spaces along the fissure and constitutes the richest and generally the only kind of ore; and

2. Country rock, altered by metasomatic processes. This as a rule contains very little, if any, gold.

The gold is generally in a finely divided state, though in many mines coarse gold also occurs. The free gold occurs in similar quantities at all depths and is generally associated with sulphides. The value of the free gold generally far exceeds that of the gold and silver in the sulphides, though in a few mines the latter may equal the former. The fineness of the gold bullion varies from 700 to 850, and averages about 800. The sulphurets, consisting of predominant pyrite with galena, blende, chalcopyrite, sometimes arsenopyrite, and small quantities of tellurides, generally make from 2 to 3 per cent of the ore, ranging from one-half to 7 per cent. The value of the sulphurets varies from $40 to $400 per ton, the quantity of silver by weight frequently exceeding that of the gold. Small quantities of bismuth and cadmium have been found. The value of the ores ranges from $6 upward. The average value is probably between $15 and $20 per ton. The Grass Valley and Banner Hill veins carry somewhat richer ore than the Nevada City mines. In structure the ore may be: (1) Massive, carrying massive quartz with irregularly distributed sulphurets. (2) Banded by deposition. Both these forms show transitions to comb structure and drusy structure. (3) Ribbon structure by subsequent movement on the vein. This is explained and illustrated in detail. The quartz under the microscope shows all phenomena of crushing, and the sulphurets are pressed out. The gold is often concentrated on the planes of sheeting by a concentration subsequent to the movement. (4) Banded structure by reopening or successive openings and fillings of a fissure.

The quartz is shown to contain soluble sulphates and chlorides.

The rocks next to the walls and fragments included in the quartz show extensive alteration to carbonates, sericite, and pyrite by metasomatic processes; the pyrite contains very little gold, and very rarely is there any free gold in the wall rock. The chemistry of the process is explained: Silica and soda are removed; potassa, lime, and sulphur are introduced. All ordinary minerals in the rocks are attacked by vein solution. A silicification of the wall rocks is not recognized.

Along certain veins there is also an extrusive mechanical alteration of the country rock, consisting in the production of schistose structure and crushing of the individual minerals.

STRUCTURE.

The simplest type of structure is produced by filling of open spaces along a single fissure, the open spaces being caused by movement along the plane of the somewhat irregular break. More complicated structure may result where there are two or more fissures, nearly parallel, the space between which is largely filled with country rock, usually brecciated or crushed. Then the quartz will deposit in the open spaces between the rock fragments, forming more or less irregular and winding veins between the parallel fissures.

The width of the quartz along the fissure varies greatly, and places

where the vein pinches out to a mere seam occur abundantly in most veins. The average width of the larger veins may be from 2 to 3 feet, while by far the largest number are very much narrower. Some of the most productive veins average but little over a foot in width.

No distinct relation between country rock and the contents of the veins can be recognized. Veins occur in practically all rocks of the district. The metasomatic processes are almost identical in all rocks. The character of the filling—the quartz—varies greatly, but is not constant for the same rock. It even varies in different parts of the same vein in the same rock. Some veins in granodiorite and argillite are rich in silver and carry abundant sulphides.

The influence of locality is very prominent; generally veins from the same vicinity carry similar ores. On the whole, the great concentration of deposits in and about the granodiorites of Nevada City and Grass Valley indicates that the veins are genetically connected with this large intrusion of acid magma.

PAY SHOOTS.

The rich ore usually occurs in fairly well-defined bodies, or pay shoots. They are, as a rule, long-drawn bodies with their maximum extension in the general direction of the dip, but with an ordinarily well defined pitch on the plane of the vein. The rule in this vicinity is that the ore shoot dips to the left of an observer standing on the apex and looking down in the direction of the dip.

The pay shoots vary in length from a few feet—those generally being called pockets—up to several thousand feet. On each larger vein there are usually several pay shoots. It is very common for one shoot to cease in depth or be subject to local impoverishment, but thorough exploration will usually result in finding new shoots or a continuation of the old one. There is no gradual impoverishment of the ore in depth, while frequent changes in value occur. The depth at which gold quartz is no longer deposited has not been reached in our present explorations.

GENESIS.

The veins were formed by aqueous deposition and by thermal waters containing carbonates, silica, alkaline sulphides and sulphates, besides gold and metallic sulphides, the latter probably in a state of solution. The heavy metals were probably leached from the rocks traversed by the solutions at a great depth. It is shown that the heavy metals in the veins have probably not been derived from the immediately adjoining wall rock, though gold and heavy metals may, and in fact do, occur in them.

The solubility of minerals at different temperatures and pressures is investigated, with the result that there is generally not an indefinite increase in solubility by rising temperature and pressure, but a certain maximum which can not be exceeded. From this it appears probable

that a decrease of temperature and pressure in waters approaching the surface is not an entirely dominant factor in the formation of mineral deposits. Considerable silica and sodium salts have been constantly subtracted from the wall rock during the vein-forming process, and a part of the quartz in the vein is derived from this silica. It is suggested that the deposition might be due to a disturbance of the equilibrium in the concentrated solution by material constantly added from the wall rock. The gold and the sulphides were probably largely deposited mechanically with the silica. The country rock appears to have had no special precipitating influence on the solutions.

THE SUPERJACENT FORMATION.

The auriferous gravels of Neocene age are briefly described, and it is shown that they had not accumulated to any considerable depth at the beginning of the volcanic period.

The bed-rock surface upon which they rested is restored and shown by contour lines. This Neocene topography is discussed in detail, and it is shown how the incongruous features of the map in regard to the grade of the streams are made harmonious by the supposition of a tilting of the Sierra Nevada along its eastern edge. The rocks of the volcanic period, including rhyolite and andesitic tuffs, are briefly described, and it is shown that much of the heavy gravel bodies of Nevada City was due to the damming of the channel by the first rhyolitic flows. The last andesitic mud flows covered the whole country here described, Banner Hill and Osborne Hill alone projecting above the level of the lava field.

ADDENDUM.

According to data kindly furnished by Mr. Charles G. Yale, statistician United States Mint, San Francisco, the production of the Nevada City and Grass Valley mining districts in recent years, including all quartz and placer mines, is as follows:

	1893.	1894.	1895.
Nevada City, including Willow Valley.	$578,523.72	$506,380.22	$642,799.76
Grass Valley, including Rough and Ready and Deadmans Flat	845,289.00	697,432.25	564,908.64
Total	1,423,812.72	1,203,812.47	1,207,708.40

INDEX.

E.

F.

O.

P.

1 sheet
5/3/93

Verify _1_ sheet (s)
in pocket

	DATE DUE		
OCT 18 1984			
APR 20 1985			
DEC 21 1985			
MAY 10 1987			
JUN 21 2001			